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MODELING THE RATED FORCE USING NETWORK FLOW AND GOAL PROGRAMMING TECHNIQUES

THESIS

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THESIS

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Preface

Many students have endured the thesis process and many more in the future will have the same pleasure. The process itself is a challenging one and certainly adds a much needed dimension to the overall degree program. There is no other way to teach the practical methods of defining and developing a real-world problem.

I can not finish this process without giving many, many thanks to my thesis advisor, Major Joe Litko. Without his expertise and overall support, I undoubtedly would not have achieved the same quality or quantity in this thesis. Additionally, I also appreciate the efforts and advice of Dr. Yupo Chan.

It goes without saying that the help and support of Major Brian Sutter and the rest of the staff of the Analysis Division at AFMPC are deeply appreciated for without them none of this would have been accomplished.

Finally, a few words to my husband Bud. He has endured many moments of impatience and frustration and has patiently stood by me throughout the entire process. His love and belief in my capabilities have often been the motivating factor for me. I can't thank him enough.

Roberta Jameson

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Attrition Rate. This is a percentage of individuals belonging to a specific group that separate from the Air Force within a given time period, usually one year.

Aviation Service Date (ASD). The date an individual starts flying duties with the Air Force.

Experience Level. Regulations outline the minimum number of flying hours and/or years of aviation duty required for an individual to be classified as "experienced."

First Assignment Instructor Pilots. Pilots who are assigned immediately after graduation from Undergraduate Pilot Training to instructor duties in Air Training Command (ATC). After serving their first tour in ATC, a specific number of these pilots are assigned to a major weapon system.

Rated Officer. This term refers to Air Force officers possessing an aeronautical rating (pilot or navigator).

Rated Staff. This term refers to staff duties performed by rated officers. In reality, a rated staff duty can include flying duties; however, in this study, rated staff refers only to nonflying duties.

Rated Supplement. Nonflying duties, traditionally filled with nonrated officers, performed by rated officers.

Undergraduate Flight Training (UFT). A formal training program where individuals recieve their aeronautical rating after successful graduation. UFT includes Undergraduate Pilot Training (UPT), Undergraduate Navigator Training (UNT), and Undergraduate Helicopter Training (UHT).

Retention Rate. This is the percentage of individuals belonging to a specific group who elect to remain in the Air Force during a given time period.

Abstract

The purpose of this ~~research~~ was to develop a model which accurately represents the rated officer force and which has the flexibility to represent how different assignment policies affect the system. The managers at the Air Force Military Personnel Center were interested in modeling the rated officer flight gate system. Flight gates are milestones that must be achieved at certain points of a rated officer's career.

This research resulted in selection of a single commodity network flow model with side constraints which also incorporates goal programming techniques. The basic network is designed to represent the rotation of rated officers between flying and nonflying duties. The only flows within the network which have costs associated with them are flows which lead to nonachievement of a flight gate. The objective function is a combination of pure flow cost minimization and minimization of deviation variables associated with various goals.

Initial results indicate the model offers managers the ability to evaluate conflicting assignment policies. Model shortcomings that need further study include the computer run time and modeling attrition as a dynamic process.

MODELING THE RATED FORCE USING NETWORK FLOW AND GOAL PROGRAMMING TECHNIQUES

I. Background

General Issue

People are a critical resource to the Air Force. In terms of both initial investment and need, the rated officer personnel in the Air Force are assets which require close monitoring. Any policies, current or projected, concerning rated force management should be analyzed with respect to the overall effect on the structure of the rated force.

The current policies affecting the rated force are incentives and the assignment options for rated officers. The Air Force, recognizing the value of the rated force, has a tradition of offering extra incentives in order to improve retention. One of these incentives, termed flight pay, was established by the Aviation Career Incentive Act of 1974. This act regulates the management process for rated officer assignments and tasks the Air Force with the responsibility of insuring that rated officers receive flight pay throughout most of their careers. The Air Force considers flight pay a major factor in retention of rated officers.

According to a joint service study group, "officer flight pay is needed for the services to attract and keep sufficient numbers of quality career aviators (20:28)". Inadequate compensation is often cited by rated officers as a major reason for separating from the Air Force (6:3).

Air Force policy also dictates the assignment of rated officers to non-flying positions (7:33). This policy provides a pool of rated officers, referred to as the "rated supplement" and "rated staff" force, who can occupy cockpit positions during a period of national emergency. Other purposes of this policy are to offer officers career broadening opportunities and to also provide rated expertise in areas of the Air Force not directly involved in flying activities.

Often the need to fill non-flying positions with rated officers conflicts with the policy of continuous receipt of flight pay for rated officers. Air Force Regulation (AFR) 36-20 outlines specifically the flying requirements necessary for continuous receipt of flight pay when assigned to non-flying duties. These requirements are as follows:

1. Perform six years of operational flying by the 12th year of aviation service.

2. Perform nine years of operational flying by the 18th year of aviation service.

3. Perform eleven years of operational flying by the 18^{th} year of aviation service to receive flight pay through 25 years of officer service. (7:11)

Rated officers assigned to flying positions always receive flight pay.

AFR 36-20 also stipulates policies which help insure maximum achievement of the the rated officer flying requirements listed above -- referred to as "gates." "It is the Air Force policy that as many members as possible perform at least 9 years of operational flying duty during the first 18 years of aviation service" (7:11). The regulation further states that graduates of undergraduate pilot training and undergraduate navigator training must be "assigned to operational flying duties until they have completed at least 6 years of operational flying duties" (7:11). The policy concerning more experienced rated officers states:

> The typical officer with over 12 years' aviation service must have completed or be able to complete at least 9 years, and preferably 11 years, of operational flying duty before the 18th year of aviation service before being assigned to nonoperational flying duty [7:11].

Compliance with the current policies of AFR 36-20 and other assignment policies requires close monitoring of the rated officer force.

A proposed policy involving the rated officer force is the concept of a career pilot force (9:1). According to this proposal, officers in the career pilot force would perform only cockpit tasks and flying-related leadership and supervisory duties. Advocates of this concept feel the creation of a career track, or "dual track", would improve pilot retention and improve the overall warfighting capability of the Air Force (9:45). There obviously are numerous schemes to implement a career pilot force but prior to any implementation, these schemes should be analyzed to determine their effect on the structure of the rated force. The effect on the career paths of individuals and the distribution of the individuals within the system should be included in this analysis.

Present Solutions

The Air Force Military Personnel Center (AFMPC) controls the assignment for all military officers. Personnel resource managers are responsible for matching people with jobs and operate under numerous rules. Regulations governing the rated force, such as AFR 36-20, are a subset of these assignment rules.

The Analysis Division at AFMPC provides information on the rated force structure to the appropriate resource managers. This information concerns long-term trends in the rated

force structure and forecasts possible areas of concern. This information is prepared by using a simple arithmetic model. This model computes the "gate supportable inventory", which is the maximum personnel inventory that will allow all members to complete a given number of flying gates (19:11). Then a comparison is made to the actual current personnel inventory. A breakdown by aircraft type and aeronautical rating is the final result of this model. This result shows, for each aircraft type and aeronautical rating, assessments regarding the capability to comply with flying gate policies. This model is insufficient because it does not consider the dynamic processes of the personnel assignment system. The Analysis Division, recognizing the shortcomings of the current model, sponsored a 1987 Air Force Institute of Technology (AFIT) Master's Thesis aimed at developing an improved model (19:1). This thesis developed a single commodity network flow model with side constraints. A specialized network algorithm was used to solve the model. In order to use the algorithm, a specific network formulation had to be designed. The result of the network formulation is a solution representing the optimal assignment policy which will minimize non-achievement of flying gates while maintaining required manning levels within the rated force (19:87). Unfortunately, this design also has many shortcomings and does not adequately model the

true nature of the problem.

First, the level of detail used is not sufficient. The model uses a one-year time increment which prevents realistic representation of duty tour lengths. This use of a one-year time increment serves to hide some of the fluctuations which normally occur in the assignment system (19:88). Second, the greatest shortcoming of the model is the method used to model attrition. The method requires user manipulation of several attrition parameters in order to achieve feasible solutions (19:89). This is a cumbersome procedure and it renders the entire model virtually unusable.

Presently, a model is not available which has the capability to evaluate conflicting objectives inherent in the personnel assignment process. Not only are personnel managers concerned with filling manning requirements, they are also concerned with monitoring individual career progression. These objectives are often conflicting and difficult to balance. A useful model would be one which could help personnel managers evaluate long-range effects of their policies and procedures.

Problem Statement

AFMPC needs an effective decision aid which will realistically model the rated force personnel flow.

Research Objectives

It is the objective of this research to develop a model, using the Tactical Airlift pilot force as a guide, which will accurately represent the interrelationships inherent in the rated force system. Additionally, the model should have the flexibility to represent how differing policies and objectives affect the structure of the rated force.

Sub-objectives.

1. Determine the specific output requirements needed by AFMPC rated force managers;
2. Determine which relationships within the rated force should be modeled in order to accurately represent the force;
3. Determine which policies should be analyzed by the completed model.

Scope of the Study

This research effort is concerned with the total rated force structure, not individuals in the structure. The model will determine optimal flows through the personnel network and will help the AFMPC analysis branch find bottlenecks in the system. The model developed by this effort will analyze a portion of the rated force; specifically pilots in Tactical Airlift career paths.

The inputs into this model are obtained from Air Force source documents and data bases and predict values such as manpower requirements, attrition levels, and entry source levels.

Summary

AFMPC Analysis Division needs a model which represents the rated officer force as it changes over time. Many personnel policies impact on the force structure; such as duty duration lengths, career progression policies, and flight gate attainment policies. These policies are often conflicting so a model which has the ability to analyze the effects of different policies would provide managers with information they need.

Chapter 2 contains a literature review of relevant journals and studies relating to manpower problems. Chapter 3 is a description of the conceptual model and the computer implementation of the model. Chapter 4 is a summary of model verification and validation. Chapter 5 contains the results of model experimentation and Chapter 6 summarizes the entire thesis effort and makes recommendations for future research.

II. Literature Review

This chapter examines the various methodologies available in the field of manpower modeling. The methods discussed have at least one possible application to the problem of rated force management. The methods fall into the following categories:

1. Simulation Methods
   a. Entity Flow Approaches
   b. System Dynamic Approachs

2. Analytic Methods
   a. Probabilistic Approaches
   b. Linear Programming Approaches
   c. Network Flow Programming Approaches

Simulation Methods

Simulation is defined as "the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies for the operation of the system" (5:41). Simulation methods are descriptive in nature; that is, they do not provide optimal solutions but they can provide insight into possible solutions. Simulation models can be categorized into two general groups: entity flow simulations and system dynamic simulations.

Entity Flow Approaches. Entity flow simulation models require a one-to-one correspondence between entities in the model and the data elements being modeled. Such models use a large source code and an extensive data base. They also require long computer run times. These models have the advantage of being fairly simplistic for the model builders and programmers, but are often difficult to maintain and modify. Some success has been achieved using entity flow simulations to model manpower systems. Charpie effectively used an entity simulation model to represent the flow of B-52 radar navigators through the personnel system (4:13-16). Leupp (16:3-8) developed a manpower model of Seabee enlisted personnel. Given an initial distribution of personnel into classes, the simulation model generated a report of changes in personnel status as a function of time. The model assumed a constant authorization structure and constant reenlistment rates. Attrition rates, promotion rates, and accesion rates were constant for any particular run of the model. The system was represented as a straightforward flow situation with constant mean rates of flow from one class to another. No informational feedback was captured in the model. This lack of informational feedback is a general criticism of entity flow simulations. It would not be efficient to model the rated force by entity flow simulation. The large number of entities would lead to a

model too large and too inefficient. Additionally, entity flow simulation methods would not be able to evaluate tradeoffs between varying policies and therefore would not satisfy the requirements of the research objectives.

System Dynamics Approaches. These models represent the aggregate level of a particular system as opposed to the more detailed level of entity flow simulations. The systems analysis approach involves the use of computer simulation models to perform policy analysis. System dynamics models are continuous and prescriptive. That is, they can provide a "best" solution or action given a menu of solutions to choose from. However, they do not have the ability to uncover new options. They duplicate system behavior characteristics so that new policies may be tested and they only superficially represent the different groups found in the system being modeled. The most important concept of the system dynamics approach is the information feedback system. This system implements information feedback control loops that channel results of decisions and policies back to the system. This leads to new decisions which, in turn, keep the system in continuous motion (15:34).

As mentioned above, system dynamic models are often used to study effects of policy changes on a given system. Knight (14:1-10) used the system dynamics approach to represent the Air Force pilot pipeline as a closed-loop

feedback control system. The model determined undergraduate pilot training (UPT) requirements based on several input parameters. It also had the flexibility to test various policies and their effects. These policies included changing the size of UPT instructor force, controlling the UPT class size, and varying the instructor-to-student ratio.

Also, Lawson (15:54) used the systems dynamic approach to model the rotation/assignment system of a particular segment of the Air Force enlisted force subject to a high number of overseas rotations. The model was designed as a policy implementation tool and addressed policies relating to changes in the airman compensation program and policies relating to changes in the manpower levels.

A system dynamics approach could be used to model the rated force structure on an aggregate level. This would allow for testing of various policies but it would not determine optimal assignment flows within the rated force.

Analytic Methods

Analytic models differ from simulation models in that they attempt to define the essence of a problem to reveal the underlying structure. In other words, an analytic model of a social process is a system of equations and related mathematical expressions that describe the essense of the problem. An analytic model concisely describes a problem

and this process hepls reveal critical interrelationships. Analytic methods may incorporate an optimization process which means they determine optimal solutions to problems. Models developed to solve manpower problems at an aggregate level fall into three broad categories. They include probabilistic approaches (Markov process models), linear programming approaches (including goal programming models), and network programming approaches.

Probabilistic Approaches. In numerous applications Markov processes have been applied to manpower modeling (3;27). These Markov models generally multiplied a vector of personnel in various categories by a matrix of transition rates. This resulted in an estimation of the system steady state over discrete or continuous time intervals. Bartholomew (1:55-93) presented variations of Markov models which covered a range of contingencies from the most basic (a system with given inputs) to the more complicated (continuous system with loss rates dependent on length of service). These models all had an important defect when applied to the flows of manpower in a personnel system. The models assumed that individuals did not act based on perceptions about their environment and, in particular, their promotion chances. It is likely an individual will separate from an organization if promotion likelihood is perceived to be low. These models did not include a

statistical relationship between separation rates and promotion rates. Introduction of this relationship would convert the problem to a nonlinear formulation and could also make it more difficult to solve (1:93).

Zanakis and Maret (28:55) also stated that Markov models cannot "consider costs, restrictions, and conflicting objectives that exist in a real world situation". The complexity of the objectives in the rated force personnel system prevents an effective solution via classical Markov processes. However, it is possible to combine Markov techniques with linear programming models in order to develop more realistic manpower models.

Linear Programming Approaches. Linear programming has been used to solve many types of manpower planning problems (2;4). In such models, the decision variables are the flows (transfers, promotions, hirings, and separations). Constraints define the relationships between the flows and the number of personnel in a given rank/classification level. Other constraints can be used to describe budgetary limitations, experience level requirements, upper and lower bounds on manpower levels and so on. The objective function is specified which will minimize (or maximize) some function of cost or effectiveness (17:187).

The first applications of linear programming to manpower planning were generally cost minimizing and produced results

which suggested hiring all low-cost personnel and firing all high-cost personnel (3:3). These results were not satisfactory because the objective function failed to take into consideration the numerous, often conflicting, objectives inherent in a personnel system. Goal programming models offer a solution to this dilemma. The objective function used in goal programming weights the "importance of various constraints and sub-objectives according to priorities expressed by one of the several decision makers" (17:187). Goal programming establishes a solution that comes as close as possible to the satisfaction of all goals. Thus, while traditional linear programming approaches stress the optimization of a single objective, goal programming approaches stress the satisfaction of multiple objectives.

There are two categories of goal programming models: weighted goal programming models and preemptive goal programming models. In matrix notation, a weighted goal programming problem can be written:

$$\text{Find } x = (x_1, x_2, \ldots . x_j) \text{ so to minimize}$$

$$a = \{g_1(n,p)\} \quad \text{such that}$$

$$f_i(x) + n_i - p_i = b_i \qquad i = 1,2,\ldots m$$

$$x,\ n,\ p > 0$$

where

$f_i(x)$ is the ith constraint,
x is the vector of decision variables,
b_i is the amount of ith resource,
n_i is the negative deviation from b_i,
p_i is the positive deviation from b_i and,

$g_1(n,p)$ is a linear function of the deviation variables (12:11-18).

In this research application, goal programming constraints could be used to model yearly manning level requirements. The right-hand side value would become a goal instead of a hard requirement and positive and negative deviation variables would also be associated with the manning level constraint. These deviation variables would then be minimized in the objective function.

In this formulation, all absolute objectives are contained in the achievement function. Price and Piskor (24:223-227) developed a weighted goal programming model to describe the manpower system for officers within the Canadian Forces. The model forms part of a control system for fixing the promotion quotas of various rank levels in any job classifications. The model was also used to evaluate proposed policy changes. An inherent disadvantage of weighted goal programming models is the difficulty determining the proper weights of goal deviations. This process must be partially or entirely repeated each time goals are added or deleted from the model. It may also be difficult to determine proper weights for non-commensurable goals. Finally, the final solution may be sensitive (insensitive) to the choice of weights (28:56).

Zanakis and Markel (28:56) stated "goal programming with preemptive priorities and possibly weighted commensurable goals within the same priority provides a more flexible and realistic tool for manpower planning problems." The significant difference of preemptive goal programming is the treatment of multiple objectives. All absolute objectives are given priority one while other objectives are given appropriate lower priorities. The achievement function for this formulation can be written:

Find $x = (x_1, x_2, \ldots, x_j)$ so to minimize

$$a = \{P_1[g_1(n,p)], \ldots, P_k[g_k(n,p)]\}$$

where P_k is the priority associated with the kth goal (12:17).

Zanakis and Markel used preemptive goal programming to project future engineering employee requirements for a chemical company. In this formulation they also used Markov transition matrices to determine annual transitions of personnel among states. The model was able to project the number of engineers needed, both company and contract, in order to meet the company's workload. It was also used to analyze the validity of various management policies (28:61).

In short, goal programming techniques can be successfully combined with other techniques to effectively model manpower systems. The rated force problem contains multiple objectives and there is no simple linear objective function

which will be true for the force at all points in time. A goal programming approach, used in conjunction with other techniques, might be successful for this particular problem.

Network Programming Approaches. Network flow theory contains many of the basic precepts found in linear programming theory. However, the use of a network formulation often is more efficient than the traditional linear (goal) programming methods. The general network representation is useful for modeling a wide range of physical and conceptual situations including manpower systems (13:1). A network is a collection of nodes which are connected by arcs. Network flow models are models in which the amount of flow on each arc is controllable and the objective is to determine values for the arc flows that optimize some measure(s) of effectiveness.

A manpower system can easily be visualized as a network. The nodes represent the state of the system at some time T and the arcs represent hires, promotions, or staying in the same state (22:1234). Grinold and Marshall (10:1-18) used networks to solve numerous types of manpower problems although they did not constrain the flows, nor did they attempt to derive flows which were optimal according to some objective function.

A true representation of a complex manpower system includes some type of objective function, either a single

objective function or multiple objectives. An example of a network with a single objective function was Olson's thesis on rated force management. The nodes represented the time (in years) and an individual's status (to include duty assignment and amount of flying credit accumulated). The arcs between nodes represented assignment decisions made by AFMPC assigmnment personnel. The node at the origination of an arc reflected the individual's status prior to beginning the duty assignment and the node at the end reflected the individual's status at the completion of the duty. The single objective was to minimize the non-achievement of flying gates (19:27-28). A specialized network algorithm, NETSID, was used to solve the model. NETSID allowed the use of side constraints but did not allow for modeling attrition as gains on the arcs. Therefore, attrition was modeled as external flows from the nodes. The output was a list of rated assignments, on an aggregate level, that AFMPC should make in order to satisfy the single objective.

As stated previously, manpower systems contain multiple objectives and can be more realistically modeled by using goal programming techniques. The literature reveals that network models of manpower systems can incorporate some aspect of goal programming. Price (22:1233-1235) described a general network formulation for goal-programming manpower models. This formulation modeled systems as capacitated

transshipment problems and solved them using advanced network codes. This general formulation was applied to a manpower problem which had previously been solved using only goal programming techniques (22:1239). The problem was a military manpower system with 28 classifications, 4 ranks in each classification and three "general service" ranks. The resulting goal program had over 600 constraints and over 1250 variables. According to Price, "a flow network model for this application would have fewer than 400 nodes and fewer than 1200 arcs" (22:1239). In general, the efficiency of solving a manpower problem with the transshipment network model algorithm is much better than that of solving the equivalent goal programming model.

Summary

This chapter initially defined the requirements for a model which effectively mirrors the rated force structure. A review of the literature revealed numerous methodologies for solving similiar manpower systems. An evaluation of these methodologies provide a basis for selecting the proper approach for realistically modeling the rated force. Chapter 3 describes additional considerations which influence the selection of a methodolgy and the chapter also contains a detailed description of the final method implemented.

III. Methodology

The purpose of this chapter is to discuss the methodology selected to model the rated force. This chapter first explains the criterion used for selection and then briefly describes the conceptual model. The remainder of the chapter is devoted to a detailed explanation of the computer implementation of the model.

Selection Criterion

The previous chapter described in detail several programming methods available for solving manpower problems. In order to determine which method to apply to the research question at hand, other considerations must be addressed. These considerations include previous models, data availability, using agencies' output requirements, and software requirements.

Previous Models. As mentioned earlier, an AFIT student thesis has already been accomplished on this specific manpower problem. (19:1) The modeling technique Major Olson used was network flow programming with side constraints. The resulting network structure was solved by using an advanced network code called NETSID which is a software package designed to solve pure minimum-cost network flow problems. The structure of the pure minimum-cost

network forced Major Olson to represent pilot attrition as negative external flows out of the network. As a result, the matrix generation program had to calculate in advance the appropriate negative external flows. This restriction resulted in a burdensome and inefficient interface between the user and the matrix generation program in order to achieve feasible solutions. However, the fact remains that the basic modeling technique used by Major Olson was valid and accurately represented the rated force structure as it changes over time.

Data Availability. The Analysis Division at AFMPC has unlimited access to the MPC data base and can extract any type of information required. The type of data needed include retention rates, duty duration lengths, and other data pertaining to assignment policies. In short, the availability of data does not prohibit the selection of any particular modeling design.

Output Requirements. The primary using agency is the Analysis Division at AFMPC. This division will be briefing the results from the model to the appropriate resource managers at AFMPC. The data primarily of interest is the distribution of the number of flight gates missed. However, decision makers also have an interest in knowing how different policies will generally affect the force structure. For example, if the average duty tour length for

a flying assignment is extended to four years, how will this affect the number of individuals in each duty type over a specific time period in the future? (26) The basic network flow model used by Major Olson has the capability to produce data which describes the aggregate rated force structure given differing policy decisions.

Software Requirements. AFMPC has requested the resulting model be solved using either the SAS software package or the MINOS software package. Both of these packages can solve large linear programming models.

Methodology Selection. After examining all the issues, the conceptual model selected is the network flow model developed by Olson. (19:27) This model is prescriptive and meets all the research objectives. However, there are some major differences related to the solution technique. In this research effort, the model is solved using classic linear programming methods and includes goal programming techniques. By employing goal programming techniques, the model's flexibility increases. Different policies and conflicting goals can be analyzed to determine their effect on the rated force structure. Additionally, changes were made concerning the way retention is modeled and the time increments of the model are shortened to half year intervals. These changes improve the realism of the model's results.

The final network structure is built through the use of a matrix generation program and solved on the MINOS software package.

Conceptual Model

The flow over time of personnel within the rated force is modeled using network flow programming. A general network model consists of nodes, some of which are connected together by arcs. The flow on the arcs represents movement of resources, such as people, as they move through the network. As resources move along arcs, there can be losses or gains to these resources. In this research application, the nodes represent the state of the manpower system at a particular time and the flows between nodes represent an assignment path which connects the nodes. Retention is modeled as gains on the arcs.

As described by Olson (19:27), the rated force structure is viewed as a four-dimensional network. The four dimensions are described as:

1. The time period;
2. The particular duty an individual is assigned;
3. The aviation service date (ASD) year group;
4. The total flying time an individual has accumulated.

Each node represents the state of the individuals at that node and the arcs between the nodes signify assignment

decisions made by AFMPC. The node at the starting point of an arc represents an individual's status immediately before beginning the duty assignment represented by the arc. The node at the end of the arc represents an individual's status at the end of the duty.

Individuals enter the network at a particular time (1st dimension) and are assigned to a specific duty (2nd dimension). Additionally, each individual is identified with an ASD year group (3rd dimension) and each individual has accumulated some flying time (4th dimension). In reality, individuals stay in a duty assignment for a given time period. During that time, his/her ASD year group increases and if the duty happens to be a flying assignment, the flying credit also increases. In terms of the network model, an individual moves from a node identified as (time,duty,ASD,fly), along some assignment path to an ending node identified as (time + duration of duty, new duty, ASD + duration of duty, fly + duration of duty). Several important points need to be emphasized . First, the duty parameter identified with each node represents the duty type of the assignment paths which lead to the node. Next, the flying credit parameter is incremented only if the assignment is a flying duty. Lastly, not all paths in the network are feasible. If a flying duty duration is three years, then only arcs which lead to nodes at (time + 3,

duty, ASD + 3, fly + 3) are feasible.

In addition to this basic network flow structure, there are some important side constraints included in the formulation. There are yearly manning levels for the rated force in each duty type. These manning levels are targets which planners attempt to meet every year. In the model, these manning requirements are treated as constraints with associated deviation variables. These deviation variables represent positive and negative deviations from the target manning level.

Computer Implementation

Implementation of the conceptual model described above is accomplished through a FORTRAN coded subroutine which builds the input matrix used by MINOS. This subroutine determines all the possible nodes in the network and all feasible arcs (assignment paths) connecting the nodes. Additionally, it incorporates numerous details which must be included to accurately model the evolution of the rated force over time. For the purposes of this research, only a segment of the rated force is modeled; the pilots in the Tactical Airlift forces. However, it is feasible that this effort be extended to include the entire Military Airlift Command (MAC) rated force structure. The changes to the model would include adding more duty types and more internal structural

constraints. A detailed user's guide for running the matrix generation subroutine, called MPSIN, is contained in Appendix A.

The MPSIN subroutine produces an input file formatted in MPS format. This file, along with an appropriate specifications file (SPECS.DAT) are all that MINOS needs to find an optimal solution.

The optimal solution found by MINOS is stored on the output file called SOL.DAT. Another FORTRAN subroutine, OUTPUT, converts the MINOS solution into a readable and useable solution format. Details for the user are located in Appendix A.

A complete listing of MPSIN and OUTPUT is in Appendix B.

Solution Algorithm. The optimization package used in this research is a FORTRAN based program called MINOS developed by Bruce Murtagh and Michael Saunders (18). MINOS stands for Modular In-Core Nonlinear Optimization System. It is designed to solve large-scale optimization problems expressed in the following standard form:

Minimize Cx

subject to $Ax = r$
$l < x < u$

where:
A is the coefficient matrix;
c is the vector of costs;
r is the vector of requirements;
x is the solution vector;
l is the vector of lower bounds;
u is the vector of upper bounds.

As used in this application, MINOS reads the MPS file created by the subroutine MPSIN, then determines an optimal set of arc flows based on minimizing the total value of the objective function and produces an output data file consisting of the optimal arc flows.

Model Assumptions. In order to model the rated force as it changes over time, several assumptions are incorporated into the MPSIN subroutine.

First, it is assumed by modeling the manpower structure at an aggregate level, there is enough detail present to gather the information needed. This assumption implies that no critical information is lost when the attributes of the individuals within the system are treated as the average of all the individuals as a whole. However, some information, such as base locations identified with the assignments, is lost due to the level of aggregation.

Next, attrition is assumed to occur at the end of a duty assignment. This assumption is necessary because retention is modeled as gains on the arcs. As a group of individuals travels along an assignment arc, only a percentage of them actually finish the trip to the ending node. This percentage, the retention rate, models the losses which occur in the real-world system.

Third, additions to the tactical airlift forces from other major command structures are considered negligible and are

not included in the model. This does not apply to FAIP accessions.

Fourth, it is assumed the model can accurately represent the system if the time is incremented at half-year time intervals. This assumption leads to other modeling assumptions:

1. All duty durations are represented as multiples of half-year increments.

2. The overall manning requirements applicable for a certain duty type and year, apply to both the first half and second half of the year.

3. All ASD year groups and flying time accumulations are represented in half-year increments.

Lastly, there are subjective hierarchies inherent in this model. These subjective elements are found in two areas:

1. The costs associated with missing a flight gate. It is assumed a hierarchy exists wherein the highest cost is associated with missing the first gate, and so on.

2. The weights of the deviation variables associated with meeting manning requirements. The weighted deviation variables are included in the objective function. These weights are subjective in nature and the hierarchy structure is not obvious.

All of these assumptions play a critical role in the development of the model structure.

<u>Model Structure</u>

The major elements of the model are the nodes, the arcs between the nodes, external flows, model constraints, and the objective function.

Each node consists of four parameters which define the dimensions of the network. These dimensions are time, duty, ASD year group, and flying credit accumulated.

The positive external flows into the nodes represent rotations into the network. The only negative external flows are used to model end-of-time-horizon requirements.

The majority of the constraints are nodal conservation constraints; flow into the node must equal flow out of the node. There are also constraints concerning the manning level requirements.

The objective function can vary depending on the type of information desired from the model. The capability to use goal programming deviation variables in the objective function gives the model additional flexibility.

The user also has the flexibility to choose the length of the time horizon for the model. This time horizon can vary from one-half year up to 10 years. Several considerations must be mentioned. If the time horizon is too short, then the model can not adequately represent long term effects on the system. On the other hand, if the time horizon is too long, the input parameters used by the model become "best-guesses" and the validity of the model's recommendations may suffer.

The forecasted manning levels and FAIP/UFT accessions used by the model are extracted from the Rated Management

Document (25). This document forecasts the requirements for the entire rated force for five years in the future. If the user selects a time horizon beyond five years, the manning levels and FAIP/UFT accessions must be estimated. The method used in this research was simply applying the data from year five to all subsequent years.

The overall size of the network (number of nodes) is a function of the node parameters. In general, the network has a maximum number of nodes which is calculated by:

(# of time units) * (# of duty types)
* (# of asd year groups)
* (of flying credit accumulation groups).

The number of constraints increases linearly with each increase in the number of nodes. This is because there is one nodal flow constraint associated with each node in the network. For a run with the parameter settings of time = 10 (5 years), duty types = 4, ASD year groups = 40 (20 separate groups), and flying credit accumulation groups = 22 (11 separate groups), the maximum number of nodes is 35200. Fortunately, many of the paths are not feasible so the number of nodes is much smaller. The actual size of the same network after MPSIN has determined the feasible paths is 6321 nodes.

Nodal Structure. Each node represents the state of the system at a particular point in time. This is

accomplished through the use of four network parameters: time, duty, ASD year group, and flying credit accumulated.

Time Parameter. The time parameter is the first dimension represented in each node. This parameter represents how often the time is incremented. Should time be incremented on a yearly basis or half-yearly basis or some other time increment? The increment chosen has a significant effect on the size of the network. This is because a change in the minimum time increment affects three dimension of the network: time, ASD year group, and flying gate credit accumulated. There is no point decreasing the time increment without also decreasing the increments for ASD year group and flying gate credit accumulation. A decrease from one year increments to .5 year increments results in nearly 8 times as many nodes.

Duty Parameter. The duty type is the second parameter represented in each node. As identified by Olson, the rated force is sufficiently represented by four duty types (19:41). These four duty types are described as:

1. Operational Flying; includes all flying duties within the major weapon system, including Advanced Student.

2. Rated Staff/Rated Supplement; includes all non-flying duties except those included in "AFIT" and "PME."

3. AFIT; includes all full-time graduate degree programs.

4. PME; includes all resident PME courses requiring a permanent change of station (this includes Intermediate Service School and Senior Service School, but not Squadron Officer School).

An average duration for each duty type was calculated from a data base provided by AFMPC. This data base contained the length of each assignment made for the past five years. The means for the four duty types are:

1. Operational Flying (OPS) - 35.182 months;
2. Rated Staff/Rated Supplement (SUP) - 33.6 months;
3. AFIT (AFIT) - 20.263 months;
4. PME (PME) - 10.864 months.

These means were rounded to the closest half year and used as a standard for the baseline runs. During the analysis portion of the thesis, the duration for OPS assignments and SUP assignments were allowed to vary.

Aviation Service Date Year Group Parameter. The third dimension identified with each node is the aviation service date (ASD) year group. Since the time parameter is incremented every half year, ASD year groups are also incremented every half year. For the purposes of this model, individuals who began flying within the same half-year period belong to the same ASD group. To illustrate how the model identifies individuals with ASD year groups, assume the model time is 1 (this is the first half of year one). Those individuals who began flying within the 6

months before the model are in ASD year group 1; those who began flying 6 months to 1 year before model time period 1 are in ASD year group 2; and so on. Since ASD represents the number of years since the initial aviation service date, each individual's ASD year group increases as time progresses.

The network representation of ASD year groups differs from reality in that the network does not differentiate individuals above ASD year group 20. All individuals with ASD year group greater than 20 are grouped together. This modeling constraint decreases the size of the network without significant loss of model accuracy.

Including those individuals who have not met the 6 month ASD group, there are 42 ASD year groups (half-year increments).

Flying Credit Accumulated. The fourth and final dimension identified with each node is the flying gate credit accumulated. As with the ASD group parameter, the flying credit parameter is incremented in half-year intervals.

The network representation of flying credit accumulated does not distinguish individuals with more than 11 years of flying credit. The reason is simply that once a pilot has accumulated 11 years of flight credit, the last flying gate requirement has been met. Any pilots with more than 11

years of flying time are grouped together in the 11 year gate credit group (the 22 group in the model).

The flight gate dimension is included so the model has a way of tracking whether individuals miss flight gates. Without this dimension it is impossible to distinguish individuals who miss flight gates. This is important because one of the major objectives of the model is minimizing the number of flight gates missed.

Network Arcs. The arcs connecting nodes in the network represent assignment decisions made by AFMPC. As previously mentioned, not all the possible paths between nodes are feasible; only certain combinations are allowed. In review, each individual's current status is defined by the parameters at the beginning node of an arc. The parameters defining the ending node of an arc represent the status of each individual after completion of an assignment. The duty parameter of the ending node indicates what duty type the arc which leads to that node represents. As individuals move along arcs (assignment paths), they are subject to some level of attrition. This attrition is handled as gains on the arcs. All arcs have an associated gain parameter. This parameter actually represents a forecasted retention rate for the ASD year group. This subject is discussed in more detail in the section on retention.

There are numerous rules used by MPSIN to determine which nodes are connected by arcs. In effect, these rules are internal structural constraints which help decrease the overall size of the network. These constraints are discussed in the section on model constraints.

Retention. Retention is defined as the percentage of individuals belonging to an ASD year group who remain in the Air Force. AFMPC forecasts the expected retention rate for each major weapon system group, aeronautical rating, and ASD year group. MPSIN treats these retention rates as gain parameters and applies them to the appropriate arcs. This causes all flows along arcs to be multiplied by the corresponding retention rate so the number of individuals who finish the assignment is some percentage of the number who started the assignment. For assignments longer than one year, attrition occurs every year.

External Flows. External flows are flows that enter or leave the network at nodes. Flows leaving the network at a node are called "negative external flows" and flows entering the network at a node are called "positive external flows" (13:2). In this research application, positive external flows represent officer rotations into the network; such as UFT/FAIP accessions.

Positive External Flows. Positive external flows represent individuals entering the network at specific nodes. In other words, the positive external flows represent the current force structure or the current career field profile. Individuals enter the network at nodes representing the expected time of their duty rotation. This expected time of rotation is calculated by adding the expected length of the current duty to the date arrived on station. The node at which individuals enter the network is also defined by the current duty, the ASD year group as of the time of rotation, and the flight gate credit level as of the time of rotation. The rotation data used by MPSIN is extracted from a data file provided by AFMPC.

Positive external flows also represent accessions to the system. These accessions come from two sources: undergraduate flight training and First Assignment Instructor Pilots. The Rated Management Document contains forecasts of these two types of accessions for the next five years. In the network these accessions are modeled as positive external flows. It is feasible to model these accessions as slack external flow variables entering the node and this would allow the model to "accept" as many of the accessions as it needed, up to a given limit. However, in reality, the weapon systems are undermanned and will always need to accept all the accessions available.

Model Constraints. Within a network structure, there are two basic types of constraints; nodal conservation constraints and side constraints.

Nodal Conservation Constraints. A network flow model requires nodal conservation of flows. That is, total flows into each node must equal total flows out of each node. The flows into each node include all the arcs entering the node plus any positive external flows. The flows out of each node includes all the arcs exiting the node plus any negative external flows (Figure 1).

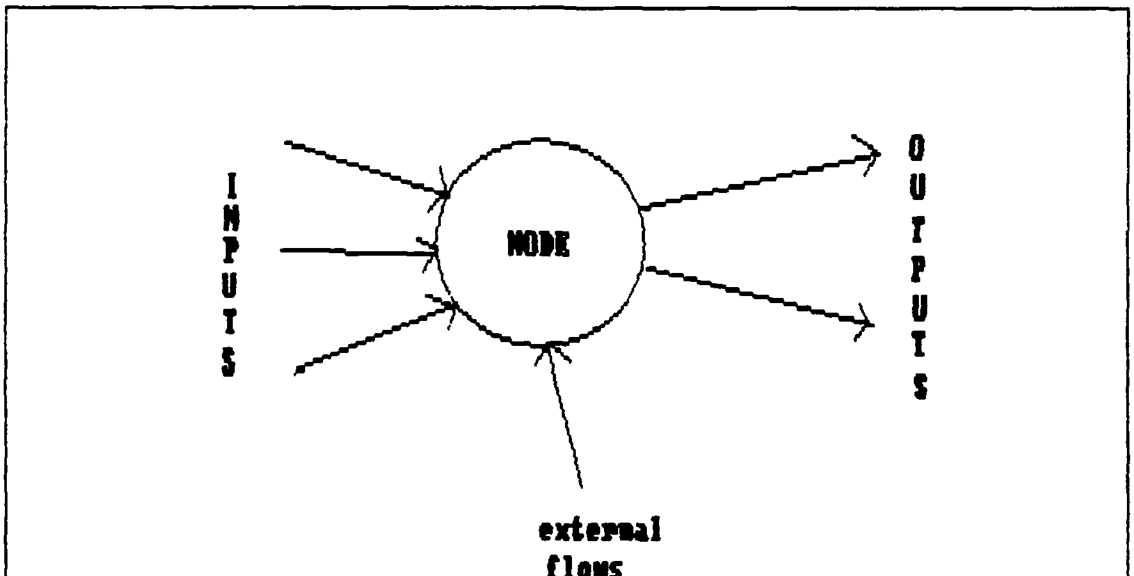


Figure 1 Nodal Conservation of Flow

In network notation, the list of arcs that originate at node i is designated as M_{Oi} and the list of arcs that terminate at node i is designated as M_{Ti}. Therefore, In a generalized network format nodal conservation of flow is shown as:

$$\sum_{k \in M_{Oi}} f_k - \sum_{k \in M_{Ti}} a_k f_k + f_{s,i} = b_i$$

where:

M_{Oi} are the flows originating at node i;
M_{Ti} are the flows terminating at node i;
$f_{s,i}$ are the slack external flows associated with the node;
a_k are the gains associated with the flows entering the node;
b_i are the external flows for the node and represent individuals entering the network.

Every feasible node in the network has a corresponding nodal conservation constraint.

Side Constraints. Side constraints are constraints which apply to flows across multiple arcs. They are used to represent manning level requirements and ending force structure requirements. These constraints are of the general form:

$$\sum_{k \in I} f_k + n_i - p_i = b_i$$

where:

I is the index set for flows associated with either the manning level or ending force requirements;
p_i are the positive deviation variables;
n_i are the negative deviation variables;
b_i are the manning level goals.

The positive and negative deviation variables may also contribute to the objective function. In the objective function these deviation variables are assigned subjective weights. The weights are chosen so there exists a hierarchy between the weights for the different duty manning constraints.

Manpower level constraints are examples of side constraints used in the model. For example, the manpower level for operational flying duties in 1989 is 1710 pilots. All arcs which lead to an operational flying duty node will contribute to this manpower constraint. There is also a positive and negative deviation variable associated with this manpower constraint. The constraint below is a simplied version of this manpower constraint:

$$\sum_{k \in I} f_k + n - p = 1710$$

where:

I are indices for flows contributing to the manning level constraint for operational flying duties in 1989;
p is the positive deviation variable;
n is the negative deviation variable;
1710 is the desired level of manning.

Most of the constraints in the network formulation are nodal flow constraints (approximately .9904 percent). The remainder of the constraints are side constraints.

Structural Constraints. Structural constraints are restrictions imposed upon the network within the MPSIN program. These constraints determine feasible nodes and feasible connections between nodes. As stated previously, not all nodes in the network are connected. MPSIN determines which combinations of duty type, ASD year group, and gate credit accumulations are possible and assigns these combinations a node number. Structural constraints also determine which nodes are connected via arcs. Unless two nodes are connected by an arc, there is no way to transition between the states represented by the two nodes. The following is a list of constraints imposed on the network structure:

1. The maximum ASD year group attainable is 25. Originally, only 21 ASD year groups were modeled in order to reduce the size of the network. In reality, individuals can progress to the 25 ASD year group.

2. The maximum gate credit accumulation possible is equal to the ASD year group or 11 years, whichever is less. In reality, individuals fly beyond 11 years of gate credit. However, once an individual has flown 11 years, the third and final flying gate has been met and there is no need for the model to track beyond 11 years flying credit.

3. Flying duties ("OPS") result in an increase to the flying credit parameter equal to the duration of the assignment. Obviously, nonflying duties do not result in any increase. Thus, arcs representing

flying duty assignments lead to nodes indicating an increase of gate credit, while arcs representing non-flying duty assignments lead to nodes indicating no increase of gate credit.

4. Pilots with less than six years of aviation service are assigned to flying duties.

5. AFIT assignments are always followed by a Staff/Supplement assignment. This parallels with the policy of serving a minimum of three years in a nonflying duty following AFIT and also with the policy that no assignment to PME is allowed until a minimum of three years has lapsed since an AFIT assignment (7:45).

6. AFIT assignments are available only to ASD year groups less than 14 years. Very few rated officers above 14 years ASD attend full-time AFIT programs.

7. A PME assignment can not follow another PME assignment.

8. PME is available to ASD year groups 12 through 14 (Intermediate Service School) and 17 and above (Senior Service School). This corresponds to the appropriate eligibility periods for assignment to these duties.

9. Attrition occurs across the duration of an assignment arc. Originally, the retention rate was applied only once across the arc for duties lasting more than one year. After discusion with AFMPC, it was decided to apply the retention rate for each year the duty lasts. For example: a three year duty with a .9 retention rate associated with the 100 individuals on the arc, only $100 * (.9)^3$ would actually complete the assignment.

10. AFIT and PME duties do not have an associated attrition rate. This mirrors reality because of the active duty service committments incurred by individuals assigned to these duties.

<u>Objective Function</u>. The model's objective function can vary depending on what information the user wants. Below are several possible objective functions:

1. Minimize the total number of flight gates missed during the time horizon of the model. This is accomplished by applying costs to certain arcs. These arcs lead to nodes with associated ASD year group and gate credit values representing a failure to meet a flying gate. For example, arcs with end-node ASD values equal to 18 years (in the model, this is the 26th ASD group due to half-year increments) or greater and gate credit values less than 9 years have an associated cost because flow along these arcs indicates failure to meet the second gate.

2. Minimize the total deviations (over the model's time horizon), from the manning requirements for flying duties. This is accomplished by placing the deviation variables associated with the manning level constraints in the objective function and minimizing the total number of deviations.

3. Minimizing the deviations from all the manning requirements for all four duty types. This is accomplished by placing weighted deviation variables associated with each type of manning level constraint into the objective function. There are four duty types each with associated manning requirements and deviation variables.

4. Any combination of the above.

There are several important points to be made. First, the actual costs assigned to the arcs leading to missed gates have an impact on the model's results. AFR 36-20 contains some guidance concerning the relative importance when comparing the three gates. A great deal of emphasis is placed on achieving the first (six-year) and second (nine-year) flying gates. There is slightly less emphasis on completing the third (eleven-year) gate. This suggests a hierarchy ranking with a greater cost applied to the first gate than the second gate and a higher cost applied to the

second gate than the third gate. In the next chapter, the sensitivity of the model is examined in relation to altering these costs.

Next, the weights associated with the deviation variables also have an impact on the model's solution. In the next chapter, the sensitivity of the model is examined in relation to altering these weights.

Ending Conditions. In order to obtain a force structure at the end of the model run which closely represents a "desired" force structure, some type of ending conditions must be included. These ending conditions give the model a goal to aim for in terms of what the force structure should consist of at the end of the model run. Without some type of ending conditions, the model may create an ending force structure which is unsatisfactory to decision makers. Within the model, flows which terminate beyond the time length of the model are routed to appropriate sink nodes. These nodes can be grouped together in various combinations. Based upon discussions with AFMPC (26), these sink nodes represent all possible combinations of ASD year group combinations and two duty types. For the purpose of the ending conditions, the two duty types are operational flying assignments (OPS) and other assignments (SUP, AFIT, and PME). For each ASD year group/duty type combination, there are corresponding desired percentages

which the model attempts to meet. For example, for ASD year group 8, the desired percentage of individuals in operational flying positions is 80 percent and 20 percent in all other duty types combined. These goals are modeled in the nodal conservation of flow constraints for these sink nodes. Since they are goals and not hard constraints, there are associated positive and negative deviation variables associated with each nodal flow constraint and these deviation variables are minimized in the objective function.

Model Inputs

The inputs for the model originate from two sets of sources. The first set of sources consists of rotation data and attrition rates from AFMPC and forecasted manning levels from the Rated Management Document. The second source of inputs is a set a parameters provided to the model by the user.

Rotation Data. This data is used to initialize the network. It is collected from the MPC data base and contains the rotation data for the tactical airlift pilot force. The format of this data file is specified in the user's guide (Appendix A).

The individuals in the data file are categorized by current duty type, ASD year group, and gate credit accumulated. For each of these duty/ASD/gate combinations,

the data file lists by time period, the total number of individuals that arrived at their current duty assignment. Using the proper duty durations and the arrived station date, the time of next rotation is determined. In addition, the node at which each group of individuals should enter the model is determined.

User Inputs. MPSIN allows the user the flexibility of adjusting internal model parameters. The following parameters can be altered by the user:

1. The time horizon of the model. This has a maximum value of 10 years (20 half-year intervals). If this parameter is adjusted, then adjustments must also be made to the number of manning requirements needed.

2. The average duty duration (in half-year increments).

3. The costs assigned to arcs associated with non-attainment of gates.

4. The accessions every half-year from UFT and FAIP sources.

5. The manning requirements for each of the duty types for the length of the model.

6. The retention rates for each ASD year group.

Model Outputs

There are several types of outputs produced by the various subroutines MPSIN, MINOS, and OUTPUT. MPSIN produces a file called MPSIN.DAT which is formatted for input to MINOS. MPSIN also produces a file called INPUT.DAT which is a file containing information on the initial characteristics of the

manpower system. Appendix C contains sample output produced from INPUT.DAT.

MINOS produces several files after the final optimal solution has been determined. The only file of interest is the file SOL.DAT which is defined in the specifications file provided to MINOS by the user. SOL.DAT contains the optimal solution and is used by the subroutine OUTPUT.

The subroutine OUTPUT creates three output files, OUTPUT.DAT, CHART.DAT, and GATES.DAT which each contain various forms of information needed by the decision maker.

OUTPUT.DAT contains information based on the final optimal solution. This information includes the optimal assignments to be made in the next five years and the number of flight gates missed in the optimal solution. CHART.DAT contains raw data which must be input to an appropriate SAS program in order to create charts for each ASD year group that show how an entering ASD year groups' characteristics change over time. GATES.DAT contains raw data which must also be input to an appropriate SAS program in order to create a chart which displays the flight gate distribution at some point in time. Figure 2 represents the relationships between all these files. Chapter 5 contains sample output from GATES.DAT and CHART.DAT and Appendix C contains sample output from OUTPUT.DAT.

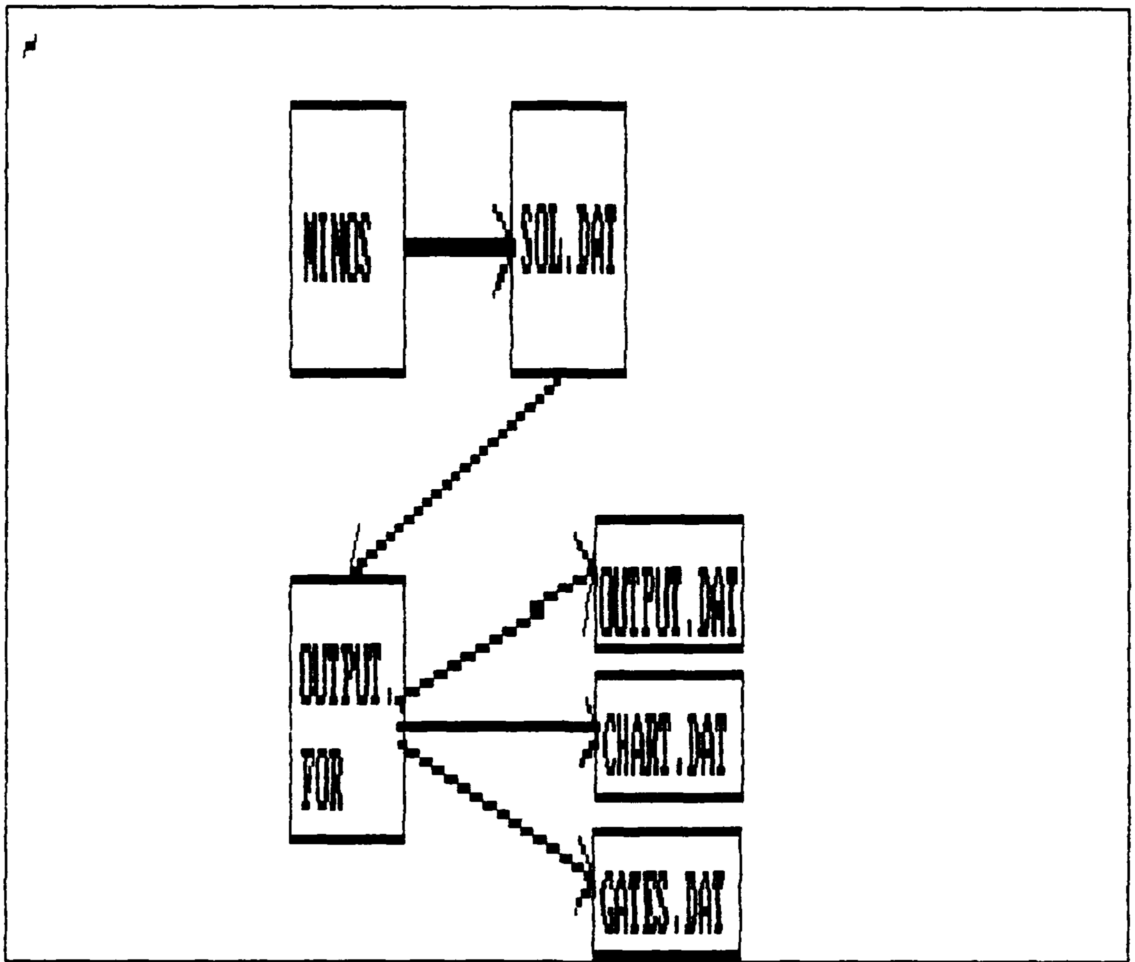


Figure 2 MINOS Output Relationships

Summary

In summary, this chapter has presented both the basic network model and how this model is represented using computer code. A brief description of the model's inputs and outputs was also included to give the reader an understanding of the computer files and operations involved with the solution technique. The next chapter presents the steps involved with model verification and validation.

IV. Verification and Validation

This chapter discusses the model verification and validation process used in this research effort.

Model Verification

Verification is the process of determining whether a model performs as it is designed to perform. According to Forrester and Senge (8:212), there are several tests which contributes to the verification process. These are the structure-verification test, the parameter-verification test, and the extreme conditions test.

Structure-Verification Test. To verify the structure of a model, a comparison is made between the structure of the real-world system and the structure of the model. A model's structure is verified if it does not contradict knowledge about the structure of the real system. According to Forrester and Senge, "..the structure of a model should match observable goals, pressures, and constraints of real decision makers..." (8:212). The network model contains a large number of the real-world constraints faced by resource managers at AFMPC. These constraints include yearly manning level requirements, yearly restrictions on the number of accessions, restrictions on which ASD year groups can attend AFIT and PME courses, and so on. A complete list of model constraints is found in the previous chapter under

structural constraints. The one structural constraint which differed significantly from the real system concerned modeling only 21 ASD year groups instead of the 25 ASD year groups actually present in the system. Originally this was done to reduce the size of the network but inclusion of this structural constraint caused some loss of realism.

The level of aggregation used by the network is necessary in order to reduce the size of the problem. Does this structure force the model to violate any knowledge about the real-world system? On an individual basis, there is information lost and all possibilities are not modeled. However, the purpose of the model is to represent the system dynamics as a whole, not on an individual basis. So, in terms of the whole system, there seems to be no knowledge violated and appropriate assumptions have been made.

Parameter-Verification Test. This test verifies model parameters against observations of real life. All the objective parameters used in the network model (attrition rates, manning levels, duty durations, etc.) were gathered from either the Rated Management Document (RMD) or directly from historical AFMPC data bases. The subjective parameters (costs for missing flight gates and the weights on deviation variables associated with the manning requirements) were selected so they fit within a relative hierarchy. These subjective parameters are measures of the decision makers'

preferences and therefore subject to variation. The model's parameters were varied across their respective ranges with runs at extreme levels to ensure the output was logical. In review, all the parameters seem to mirror the real-world system.

Extreme-Conditions Test. The purpose of this test is to subject the model to an extreme condition and compare the results of the model to expected results of the real system. In this research problem, the model was initialized with levels of manpower significantly below the requirements needed. In particular, the initial manning levels for the operational flying positions were set at approximately 83% of the desired levels. The final optimal solution decreased the manning levels in the rated staff/supplement fields in order to meet the manning requirements in the operational flying fields. This mirrors what would occur in the real world system.

Model Validation

According to Forrester and Senge, "validation is the process of establishing confidence in the soundness and usefulness of a model" (8:210). Forrester and Senge believe that confidence in a model is the ultimate goal of validation. They state, "we believe confidence is the proper criterion because there can be no proof of the

absolute correctness with which a model represents reality" (8:211). They also point out that confidence is a relative concept in the sense that it can only be assessed relative to a particular purpose. In other words, the model's usefulness must be measured in terms of the original purpose of the model. The purpose of this network flow model is to represent the rated force as it changes over time on an aggregate level and to subsequently find an optimal flow of personnel through the network. The means used to establish confidence in the model were behavior-sensitivity tests.

Behavior-Sensitivity Tests. The purpose of the behavior-sensitivity test is to measure the model's behavior to changes in parameter values (8:222). This test is conducted by systematically experimenting with different parameter values and analyzing their impact on critical model outputs. By performing these experiments, it can be determined which parameters have a significant impact on the model. Additionally, this test will give a greater understanding of the interrelationships within the system. The tool used to perform this behavior-sensitivity test is response surface methodology.

Response Surface Methodology (RSM). In this study, RSM is used to evaluate whether the model behaves in a logical manner as input parameters are varied. Additionally, RSM is used to develop a metamodel which

describes the interrelationships of the critical input parameters and their relationship to several output measures. This metamodel will initially start with fifteen factors. Although the number of factors which affect the system is greater, these fifteen factors are ones which are likely to vary in their values. There are two separate output variables of interest in the analysis: the total number of missed flight gates during the model's time horizon (Y_1), and the total deviation from manning level requirements for flying assignments expressed as a percentage (Y_2).

To determine which factors are significant, a Plackett-Burman screening *experiment* is used (21:323). The fifteen factors and the factor ranges are shown in Table 1.

Factor	Type	Low	High
RET1	1-7 ASD year group retention	1.00	.9
RET2	8-10 ASD year group retention	.9	.4
RET3	11-13 ASD year group retention	.98	.38
RET4	14-16 ASD year group retention	.98	.48
RET5	17-19 ASD year group retention	.9	.4
RET6	20+ ASD year group retention	.7	.3
OPSDUR	Duty duration flying duties (years)	5	2
SUPDUR	Duty duration rated supplement (yrs)	5	2
1GATE	Cost for missing first flight gate	8	4
2GATE	Cost for missing second flight gate	4	2
3GATE	Cost for missing third flight gate	4	1
PME#	Weight for PME deviation variables	.23	.067
AFIT#	Weight for AFIT deviation variables	.23	.067
SUP#	Weight for SUP deviation variables	.8	.3
OPS#	Weight for OPS deviation variables	.23	.067

Table 1. Factors for the Plackett-Burman Screen Test

The factors RET1 through RET6 are the retention rates for the corresponding aviation service date (ASD) year groups. The ranges on these factors were varied from a worst-case scenario to a best-case scenario for retention. The factors OPSDUR and SUPDUR are duty duration lengths for the corresponding duty types and these ranges are the minimum and maximum values for duty duration. The factors 1GATE, 2GATE, and 3GATE are the costs assigned to network flows which lead to nodes representing nonachievement of flight gates. The ranges were chosen so that the cost of missing gate 1 was always higher than the cost of missing gate 2 or gate 3. Finally, PME#, AFIT#, SUP#, and OPS# are the weights assigned to the deviation variables associated with

the manning level constraints. These ranges were chosen in order to maintain a relative hierarchy among the weights. Specifically, the OPS# should always be higher than any of the other three, even when OPS#=.3. The other three weights, SUP#, AFIT#, and PME# were all set equal to each other at both ends of the scale.

To identify the significant factors for the linear model, a fractional factorial experiment could be used. However this would require many more runs. The Plackett-Burman test requires only 16 runs and gives independent estimates of all the main effects. A single run of the model can take from 28,000 to 140,000 CPU seconds (with an average run time of 90,000 CPU seconds); therefore, the determining reason for selecting experimental designs is the number of runs required.

The resulting ANOVA tables from the Plackett-Burman test are shown in Table 2 (output Y_1) and Table 3 (output Y_2).

Source of Variation	df	Sum of Squares	Percentage of Sum of Squares
Model	5	172661.502	87.799
RET4	1	7128.84	3.625
RET6	1	39040.92	19.853
OPSDUR	1	78768.623	40.054
SUPDUR	1	19385.689	9.858
AFIT#	1	28337.514	14.4098
Error	10	23993.159	
Total	15	196654.662	

Table 2 ANOVA for the Plackett-Burman Screen for Y_1

Source of Variation	df	Sum of Squares	Percentage of Sum of Squares
Model	5	.12744458	79.423
RET1	1	.0268878	16.756
RET3	1	.0098555	6.142
RET6	1	.0377428	23.352
OPSDUR	1	.0425494	26.517
2GATE	1	.0104091	6.487
Error	10	.033019	
Total	15	.160463	

Table 3 ANOVA for the Plackett-Burman Screen for Y_2

As reflected in the ANOVA tables, there are eight

significant factors to carry forward into the next level of experimentation. This table also shows how much variance is explained by each of the factors. These factors are RET1, RET3, RET4, RET6, OPSDUR, SUPDUR, 2GATE, and AFIT#. Using these factors, the expressions representing Y_1 and Y_2 are:

$$Y_1 = 146.105625 + 21.1081X_4 + 49.39688X_6 - 70.1644X_7 - 34.8081X_8 - 42.08344X_{13}$$

$$Y_2 = .70631875 + .04099375X_1 + .02481875X_3 + .048569X_6 - .05156875X_7 + .02550625X_{10}$$

The network flow problem is solved using a deterministic method, namely linear programming, and therefore there will be no random error introduced in the statistical measures.

After reviewing the various outputs produced at each of the 16 runs, several structural changes were made to the model before proceeding to the next step. First, the model's run length was extended from 5 years to 7 years. This change allows all the initial flows into the network to enter and helped stabilize the network so a better estimate of policy changes can be determined. Next, the weight variable for PME was set to a relatively large value (a value of 1 was used). This was done because the model was allowing large deviations to occur from desired PME levels. In particular, the model was allowing positive deviations as large as 100.

A 2^{8-4} resolution IV fractional factorial experiment was used for the next level of screening. The actual design is found in Appendix D. The resulting ANOVA tables for the outputs Y_1 and Y_2 are shown below:

Source of Variation	df	Sum of Squares	Percentage of Sum of Squares
Model	3	113104.162	94.4949
RET6	1	4378.469	3.6581
OPSDUR	1	105297.005	87.9722
SUPDUR	1	3428.688	2.8646
Error	12	6589.432	
Total	15	119693.432	

Table 4 ANOVA for Fractional Factorial Test for Y_1

Source of Variation	df	Sum of Squares	Percentage of Sum of Squares
Model	3	.029444	80.25
RET1	1	.0029867	8.14
RET6	1	.0060373	16.455
OPSDUR	1	.0204204	55.656
Error	12	.0072458	
Total	15	.03669014	

Table 5 ANOVA for Fractional Factorial Test for Y_2

The residual plots for both outputs are found in Appendix D. Evaluation of these residual plots show no outliers in the data. Since there is no inherent randomness in a deterministic model, it is not necessary to evaluate normality or constant variance assumptions.

The critical factors are as follows:

RET1 - Retention for 1-7 year group;

RET6 - Retention for 20+ year group;

OPSDUR - Duty duration for OPS duty types and;

SUPDUR - Duty duration for SUP duty types.

The resulting expression for Y_1 is:

$$Y_1 = 183.30375 + 16.5425X_5 - 81.1238X_6 + 14.63875X_7$$

The adjusted R^2 for this equation is .8976. As a reminder, this value only represents any lack-of-fit present in the equation.

This expression reveals that the number of flight gates missed increases as the retention of the 20+ year group increases. This happens because there is a larger proportion of individuals in these year groups who miss flight gates (specifically the third flight gate). The number of missed flight gates also increases as the duty duration for rated supplement increases. This happens because as individuals are

assigned to rated supplement positions, they will spend more time in these duties and thus miss flight gates. The number of flight gates missed decreases as the duty duration for operational flying assignments increases. This happens because once individuals are assigned to a flying duty, they will stay in the duty for a longer period of time and the likelihood of missing a flight gate decreases.

Even though the remainder of the factors are not statistically significant, their regression coefficients may provide further confidence in the model. The retention factors RET1, RET3 and RET4 have small positive coefficients which reflect that as retention increases in these year groups, a small increase will occur in the number of missed flight gates. The factors PME#, AFIT#, and SUP# all have a small positive coefficient while OPS# has a small negative coefficient. This means that as the weights for PME, AFIT, and SUP are increased, the number of missed flight gates increases. This effect occurs because as the weights for these three duty types increases, the model forces more individuals into these duties and these individuals will not accumulate flying credit. However, as the weight for OPS is increased, the number of flight gates missed decreases. Again, as

the model forces more individuals into flying duties it makes sense that the number of flight gates missed will decrease. Up to this point all the coefficients for the factors have made intituite sense. However, the retention factors RET2 and RET5 have a small negative coefficient which reflects that as retention increases for year groups 8-10 and year groups 15-17, the number of missed flight gates will decrease. Also, the factors 1GATE, 2GATE, and 3GATE all have small positive coefficients. This means that as the cost of missing a flight gate increases, the actual number of flight gates missed will increase. These results seem counter-intuitive but in reality the coefficients are small and are a function of the regression process and not an indication of what occurs in the real system.

The resulting expression for Y_2 is:

$$Y_2 = .9293375 + .0136625X_1 + .019425X_5 + .035725X_6$$

The adjusted R^2 for this equation is .7531.

This expression reflects that the percentage of filled flying positions increases as the retention rates for 1-7 year group and 20+ year group increases. This occurs because as the retention increases, there are more individuals in these year groups. Individuals in these year groups are most often assigned to flying

positions, therefore the percentage of filled flying positions increases. This percentage also increases as the duty duration for flying duties increases.

As before, the non-significant factors can provide some insight into the model's performance. The retention factors all have a small positive coefficient associated with them. This means that as retention increases for any year group, the number of filled operational flying positions also increases. The factor SUPDUR has a small negative coefficient, which reflects that as the duty duration for rated supplement duties increases, the number of filled operational flying duties decreases. The factors 1GATE, 2GATE, and 3GATE all have small positive coefficients. This means that as the cost of missing a flight gate increases, the number of filled operational flying positions also increases. Finally, the factors AFIT# and PME# have negative coefficients and SUP# and OPS# have positive coefficients. This means that as the weights for AFIT# and PME# increase, the number of filled operational flying positions decreases. Also, as the weights for SUP# and OPS# increase, the number of filled operational flying positions increases.

Up to this point in the RSM process, no tests for interaction effects have been attempted. To find if

any interaction effects were present, a full-factorial 2^3 experimental design was conducted. The results showed no interaction effects present. The results from this experiment are not presented because the resulting regression equations did not improve upon the previous regression equations.

Conclusion

This chapter described the verification and validation process used for the network flow model. The verification tests provided a good foundation from which to continue further verification tests once the model is in constant use. The validation tests thus far have been used to build confidence in the model in its current form. The RSM process provided insight into the model's structure and how accurately the model represented the real system. As a result of this RSM process, problems with the initial model design were found when evaluating the reasonableness of the model's output. As a result, several changes were made to the initial design. The model's run length was extended from 5 years to 7 years. This change allows all the initial flows into the network to enter and helped stabilize the network so a better estimate of policy changes can be determined. Next, the weight variable

for PME was set to a relatively large value (a value of 1 was used). This was done because the model was allowing large deviations to occur from desired PME levels. In particular, the model was allowing positive deviations as large as 100.

The RSM process also revealed which input factor(s) have critical effects on two separate output measures. The results show that the duty duration for operational flying duties has the most impact on the output measures.

The purpose of the RSM process was to determine which input factors were critical and to also evaluate how well the structure of the network accurately represents the true world. True validation tests will not be possible until the model is used by the AFMPC Analysis Division on a regular basis.

V. Results

This chapter presents the results obtained from the network flow model. The chapter begins with a discussion of the model's flexibility and possible uses. The discussion continues with a description of some specific model runs and their results.

Model Flexibility

A basic goal of this research was to develop a model with the flexibility to describe differing assignment policies within the rated force. A secondary goal was to produce output which is both meaningful and useful to appropriate decision makers. The network flow model, with goal programming techniques incorporated, satisfactorily meets both these goals.

The use of goal programming allows the user to identify critical goals and then insure these goals are included in the objective function. For example, if a critical goal is to meet manning levels as close as possible, then the deviation variables associated with the manning level constraints should be placed in the objective function where they are minimized. In this manner, many separate and possibly conflicting goals can be evaluated. This can be accomplished by weighing the appropriate deviation variables which are associated with the goals and then minimizing

these deviation variables in the objective function. There are many possible variations of the objective function each describing different goals or policies.

The output produced by this model also incorporates some options for the user. The output produced by the output subroutine consists of three separate files each containing different pieces of information. Two of these files, CHART.DAT and GATES.DAT, contain raw data which must be processed by appropriate SAS programs. The data in CHART.DAT, once processed, will show how each initial ASD year group changes across the time span of the model. An example of this output is found in Figures 4 and 5. This data can be used to identify bottlenecks in the rated force system. If all the individual ASD graphs are examined for a particular time, the number of pilots who need to rotate into flying positions can be determined. This number represents how many available flying slots AFMPC resource managers need to set aside for pilots rotating from nonflying duties.

The data in GATES.DAT,once processed, will show the flight gate distribution for ASD year group. An example of this output is found in Figure 3. This data can be used to determine the flight gate distribution within the rated force at some future time.

The information presented in OUTPUT.DAT actually consists

of four different pieces of information. The optimal assignment policy for each year, as determined by MINOS, is printed. This data lists by ASD year and duty type, the number of individuals to assign. Next, the total number of flight gates missed over the time span of the model is printed. This data is presented in an aggregate form and is used as a measure of overall model performance. The third piece of information compares the desired manning levels to the manning levels determined by MINOS. This data is another measure of model performance and allows the user to see where the manpower levels are allocated.

Model Uses

There are many possible uses of the model. The purpose of this section is to illustrate some of these uses and to make comparisons of the results.

Policy Evaluation. As previously mentioned, the primary use of the network model is to evaluate policies and conflicting goals. The major tool used to accomplish this is the model's objective function.

In a simple network flow problem, the objective function minimizes or maximizes some combination of flow costs. In the formulation presented in this paper, a portion of the objective function consists of minimizing flow costs; the remainder of the objective function consists of minimizing

deviation variables. The flow costs are associated with those flows which lead to nonachievement of flight gates. The deviation variables found in the objective function are associated with constraints which in turn represent goals to be achieved. These goals, or constraints, are actually listed as side constraints within the model.

In order to illustrate the effect on the model output measures of different goals, several computer runs were accomplished with different objective functions. The first run accomplished was the baseline run, because only the sum of the flow costs leading to nonachievement of flight gates was minimized. The second run incorporated into the objective function the deviation variables associated with manning level side constraints. Finally, the third run added the deviation variables associated with meeting the ending force structure goals. The results of these three runs were compared by evaluating the same two output measures used in the RSM process in Chapter 4. Table 6 shows the summary of these results.

RUN#	Flight Gates Missed	Percentage of Filled Operational Flying Positions
Base	2nd Gate - 2.0 3rd Gate - 40.43	.8781
2	2nd Gate - 2.0 3rd Gate - 41.33	.87576
3	2nd Gate - 2.0 3rd Gate - 41.33	.87628

Table 6 Results of Different Objective Functions

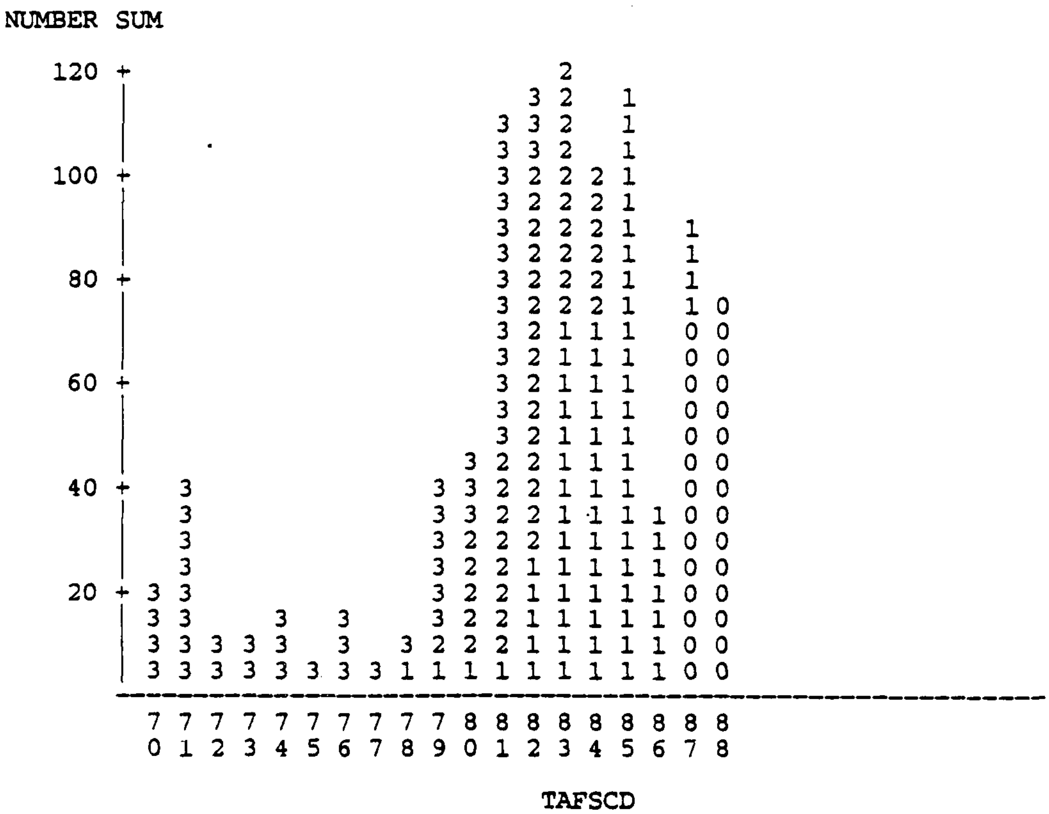
At first glance, it seems the baseline run (no goals in the objective function) gives the "best" measures of performance. However, Table 6 does not reflect how well each formulation meets the individual manning requirements for each half year. The baseline run does not perform well at all in this category. For example, it does not schedule any individuals for PME duty for the first three years and assigns an average of 120 individuals to PME for the last three years. (The requirement for PME per year is 60). The same problems occur, to a lesser extent, for the other duty types in the baseline run. Both Run 2 and Run 3 do not schedule any individuals for the first two years but in the years following these runs schedule close to 60 individuals every year. The differences between Run 2 (minimization of manning level deviations) and Run 3 (same as Run 2 but also includes minimization of ending condition deviations), are certainly not as radical. In fact, given the current output

measures available, there are no significant differences. However, the inclusion of the ending condition deviations in the objective function allows the user to specify a goal for the ending force structure.

In order to demonstrate one kind of output available to the user, the gate distribution chart for Run 1 is shown in Figure 3. This gate distribution is actually a forecast of the gate distribution at five years in the future (1993). This chart shows for each year group the gate distribution for that year group.

Force Structure Design. The model's ending conditions are designed such that a specific force structure becomes one of the model's goals. Specifically, the last nodes in the model, the sink nodes, are divided into ASD year group and duty combinations. However, AFMPC was only concerned with splitting the duty types into flying and nonflying categories for those sink nodes. Percentages were provided by AFMPC which described the desired force structure at the end of the model's run. These percentages were given in terms of groups of ASD years and are shown below.

GATES.DAT FOR RUN#3
FORECAST FOR 1993



SYMBOL	GATE	SYMBOL	GATE	SYMBOL	GATE	SYMBOL	GATE
0	0	1	1	2	2	3	3

Figure 3 GATES.DAT Output for RUN 1

ASD Year Group	% Flying	% Nonflying
1 - 4	100	0
5 - 10	90	10
11 - 16	40	60
17 and above	33	67

Table 7 Ending Force Structure Goals

As previously stated, these percentages are treated as goals and thus have associated deviation variables which are minimized in the objective function. In order to determine the effect, if any, of changing these force structure goals, several computer runs were made with different percentages used. Run 1 used the percentages shown in Table 7 and run 2 used the percentages shown in Table 8.

ASD Year Group	% Flying	% Nonflying
1 - 4	100	0
5 - 10	90	10
11 - 16	60	40
17 and above	67	33

Table 8 Ending Force Structure Goals (Run 2)

The results of these two runs were compared by evaluating the number of flight gates missed and by evaluating the percentage of filled duty positions for all four duty types. These comparisons are shown in Table 9.

RUN #	Flight gates missed	% of OPS	% of SUP	% of AFIT	% of PME
1	2nd gate - 2.0 3rd gate - 41.33	.87576	.143	.55	.713
2	2nd gate - 3.2 3rd gate - 42.53	.8767	.144	.55	.713

Table 9 Results from Ending Condition Runs

This table shows very slight differences for the changes made in the ending conditions. However, there were some changes and this means that the ending conditions do have an impact on the optimal solution.

In order to demonstrate how these changes in the ending conditions affects specific ASD year groups, one chart for ASD year group 10 was created. These charts are duplicated in Figures 4 and 5.

CHART.DAT FOR RUN 1
ASD YEAR GROUP 10

```
NUMBER SUM

24 +  333  333
   |  333  333
   |  333  333
   |  222  222  333  333
21 +  222  222  333  333
   |  222  222  333  333
   |  222  222  222  222  333  333
   |  222  222  222  222  333  333
18 +  222  222  222  222  333  333
   |  222  222  222  222  222  222  333  333
   |  222  222  222  222  222  222  333  333
   |  222  222  222  222  222  222  333  333
15 +  222  222  222  222  222  222  222  222  333  333
   |  222  222  222  222  222  222  222  222  333  333
   |  222  222  222  222  222  222  222  222  333  333  333  333
   |  111  111  222  222  222  222  222  222  222  222  333  333  333  333
12 +  111  111  222  222  222  222  222  222  222  222  333  333  333  333
   |  111  111  111  111  222  222  222  222  222  222  222  222  333  333  333
   |  111  111  111  111  222  222  222  222  222  222  222  222  222  222  333
   |  111  111  111  111  222  222  222  222  222  222  222  222  222  222  333
 9 +  111  111  111  111  111  222  222  222  222  222  222  222  222  222  222
   |  111  111  111  111  111  111  222  222  222  222  222  222  222  222  222
   |  111  111  111  111  111  111  222  222  222  222  222  222  222  222  222
   |  111  111  111  111  111  111  222  222  222  222  222  222  222  222  222
 6 +  111  111  111  111  111  111  111  111  222  222  222  222  222  222  222
   |  111  111  111  111  111  111  111  111  111  111  222  222  222  222  222
   |  111  111  111  111  111  111  111  111  111  111  111  111  111  111  222
   |  111  111  111  111  111  111  111  111  111  111  111  111  111  111  111
 3 +  111  111  111  111  111  111  111  111  111  111  111  111  111  111  111
   |  111  111  111  111  111  111  111  111  111  111  111  111  111  111  111
   |  111  111  111  111  111  111  111  111  111  111  111  111  111  111  111
   |  111  111  111  111  111  111  111  111  111  111  111  111  111  111  111
   ----------------------------------------------------------------------------
       0   .5    1   1.5   2   2.5   3   3.5   4   4.5   5   5.5   6   6.5   7

                                 TIME

           SYMBOL DUTY     SYMBOL DUTY     SYMBOL DUTY

             1    OPS        2    SUP        3    AFIT
```

Figure 4 CHART.DAT Output for RUN 1

CHART.DAT FOR RUN 2
ASD YEAR GROUP 10

```
NUMBER SUM

24 +  333  333
   |  333  333
   |  333  333
   |  222  222  333  333
21 +  222  222  333  333
   |  222  222  333  333
   |  222  222  222  222  333  333
   |  222  222  222  222  333  333
18 +  222  222  222  222  333  333
   |  222  222  222  222  222  222  333  333
   |  222  222  222  222  222  222  333  333
   |  222  222  222  222  222  222  333  333  333  333
15 +  222  222  222  222  222  222  222  222  333  333
   |  222  222  222  222  222  222  222  222  333  333  333  333
   |  222  222  222  222  222  222  222  222  222  222  333  333
   |  111  111  222  222  222  222  222  222  222  222  333  333  333  333
12 +  111  111  222  222  222  222  222  222  222  222  222  222  333  333  333
   |  111  111  111  111  222  222  222  222  222  222  222  222  333  333  333
   |  111  111  111  111  222  222  222  222  222  222  222  222  222  222  333
   |  111  111  111  111  222  222  222  222  222  222  222  222  222  222  222
 9 +  111  111  111  111  111  222  222  222  222  222  222  222  222  222  222
   |  111  111  111  111  111  111  111  111  222  222  222  222  222  222  222
   |  111  111  111  111  111  111  111  111  111  111  222  222  222  222  222
   |  111  111  111  111  111  111  111  111  111  111  111  111  222  222  222
 6 +  111  111  111  111  111  111  111  111  111  111  111  111  111  111  222
   |  111  111  111  111  111  111  111  111  111  111  111  111  111  111  111
   |  111  111  111  111  111  111  111  111  111  111  111  111  111  111  111
   |  111  111  111  111  111  111  111  111  111  111  111  111  111  111  111
 3 +  111  111  111  111  111  111  111  111  111  111  111  111  111  111  111
   |  111  111  111  111  111  111  111  111  111  111  111  111  111  111  111
   |  111  111  111  111  111  111  111  111  111  111  111  111  111  111  111
   |  111  111  111  111  111  111  111  111  111  111  111  111  111  111  111
   ----------------------------------------------------------------------------
       0    .5    1   1.5    2   2.5    3   3.5    4   4.5    5   5.5    6   6.5    7

                                    TIME

             SYMBOL DUTY      SYMBOL DUTY      SYMBOL DUTY

               1    OPS         2    SUP         3    AFIT
```

Figure 5 CHART.DAT Output for RUN 2

Duty Duration. The RSM sensitivity analysis performed in Chapter 4 found the duty duration for OPS and SUP to a lesser degree both have a significant impact on the optimal solution. For this reason, a change was made to the network to allow for different duty durations for OPS and SUP duty types. In this revision, three different duty durations were assigned to OPS and SUP duty types. In the network this meant there were three arcs leaving each node associated with a OPS or SUP duty assignment. The three different duty durations used in this example were 3, 3.5, and 4 years (Run 1). This formulation was compared against a formulation with only one duty duration (4 years) for both OPS and SUP (Run 2). The results from this comparison are found in Table 10.

RUN#	Flight Gates Missed	% of OPS	% of SUP	% of AFIT	% of PME
1	2nd Gate - 2.0 3rd Gate - 41.33	.87576	.143	.55	.713
2	2nd Gate - 2.0 3rd Gate - 47.86	.87786	.1575	.558	.685

Table 10 Results from Different Duty Durations

These results show that by allowing for different duty durations, the model does indeed find a different optimal solution. This is expected because different duty durations have a significant effect on the optimal solution. This type of formulation may be more accurate and useful because

it allows different duration lengths. The original formulation assumes the duty durations for OPS and SUP duty types are an average value. In reality, the duty durations for these two duty types can vary from individual to individual, depending on the other constraints inherent in the manpower system.

Summary.

In summary, this chapter has illustrated the flexibility of the model and its current uses. The discussion of the current uses of the formulation showed the flexibility of the model and should help the user understand how the model can be used to evaluate different policies and goals. The next chapter discusses the shortcomings and limitations of the current model and also lists several recommendations for future research.

VI. Observations and Recommendations

This chapter discusses some of the general observations resulting from this research. Topics discussed include the shortcomings and limitations of the model, and recommendations for future research efforts.

Shortcomings and Limitations

The network flow model developed in this research offers increased insight of the management of the rated force. However, it is still not a perfect solution and contains some shortcomings. Resolution of these shortcomings could improve the usefulness of the model.

Model Run Time. Model run time refers to the total CPU time which MINOS takes to find an optimal solution to the linear programming problem. For a model run time of seven years, the normal CPU time is approximately 80,000 seconds. This run time is a direct function of the large number of nodes and constraints present in the network. This model run time could be prohibitive depending on what type of computer system is used.

There are a couple of solutions to this problem. First, research might find there are alternative solution algorithms, other than the classic linear programming approach, which might offer improved run times. The matrix density of the current network is approximately 6 percent

which suggests that an algorithm which exploits this attribute might be a likely alternative. Additionally, only 1 percent of all the model constraints are side constraints; the remainder are nodal conservation of flow constraints. Finally, Karmarkar's algorithm might shorten the run time enough to make the classic linear programming approach as used in this formulation attractive (11:75-90).

ASD Structure Representation. Currently, the model groups all ASD year groups greater than 20 in one ASD year group category. Once grouped into this category, all individuals are considered to have the same attrition rate and the same duty durations. This was done to help reduce the size of the network during the development and testing stages. Use of this simplified grouping actually reduces the validity and accuracy of the model because the actual retention rates and assignment policies may differ significantly for individuals above 20 years ASD time. The solution to this problem is very simple and is outlined in the user's guide found in Appendix A.

Force Aggregation. As discussed in Chapter 3, some details of the real system are omitted in the model formulation. Specifically, there is no attempt to model the manning and experience requirements for separate bases. Obviously, these are real-world requirements that the resource managers at AFMPC must consider along with all the

other constraints now modeled. The individual base requirements could be included in the formulation but this would significantly increase both the size and complexity of the network. An additional dimension, representing the bases, would need to be added. Additionally, side constraints representing manning and experience level requirements for each base would need to be included. The number of nodes in the network would multiply from the current number by the number of bases the user wants to model. The number of constraints in the network would also increase.

Before attempting to add this level of detail to the model, the user should evaluate the tradeoffs between increased detail and network size. This change should only be necessary if the aggregate model does not provide enough flexibility for AFMPC resource managers to effectively assign personnel at the base level. However, by including this extra dimension and the necessary side constraints, the real-world system would be more accurately represented.

Attrition. In this formulation, attrition is modeled as gains on the arcs. The yearly attrition values for each ASD year group are gathered from AFMPC and are applied to all flows representing operational flying or rated supplement assignments. Unfortunately, AFMPC only forecasts attrition one year into the future so attrition values

beyond one year are assumed to be the same as the forecasts for the first year. Obviously, this is not a good assumption but it is better than no attrition forecasts at all.

An argument can be made that attrition is a function of an officer's career path. If a pilot has served all his/her assignments in flying duties, then he/she might be more likely to stay in the Air Force. On the other hand, a pilot who has been forced to serve in nonflying positions may be very likely to leave the Air Force. Based on this assumption, attrition could be modeled as a stochastic process in the sense that the attrition rate for a specific arc would be a function of what assignments preceded the arc. It is possible to develop some type of dynamic formulation to model this type of system. An example using a reduced network formulation of six nodes and two dimensions (time and duty) is shown in Figure 9.

This example uses two duty types, OPS and SUP, and three time periods. For simplicity, duty durations are assumed to be only one time period in length. A pilot who has reached node (time=3,duty=OPS) by first passing through node (time=2,duty=OPS) would have one attrition rate but a pilot who has reached node (time=3,duty=OPS) by passing through node (time=2,duty=SUP) would have a higher attrition rate. Pilots can reach node (time=3,duty=SUP) by three different

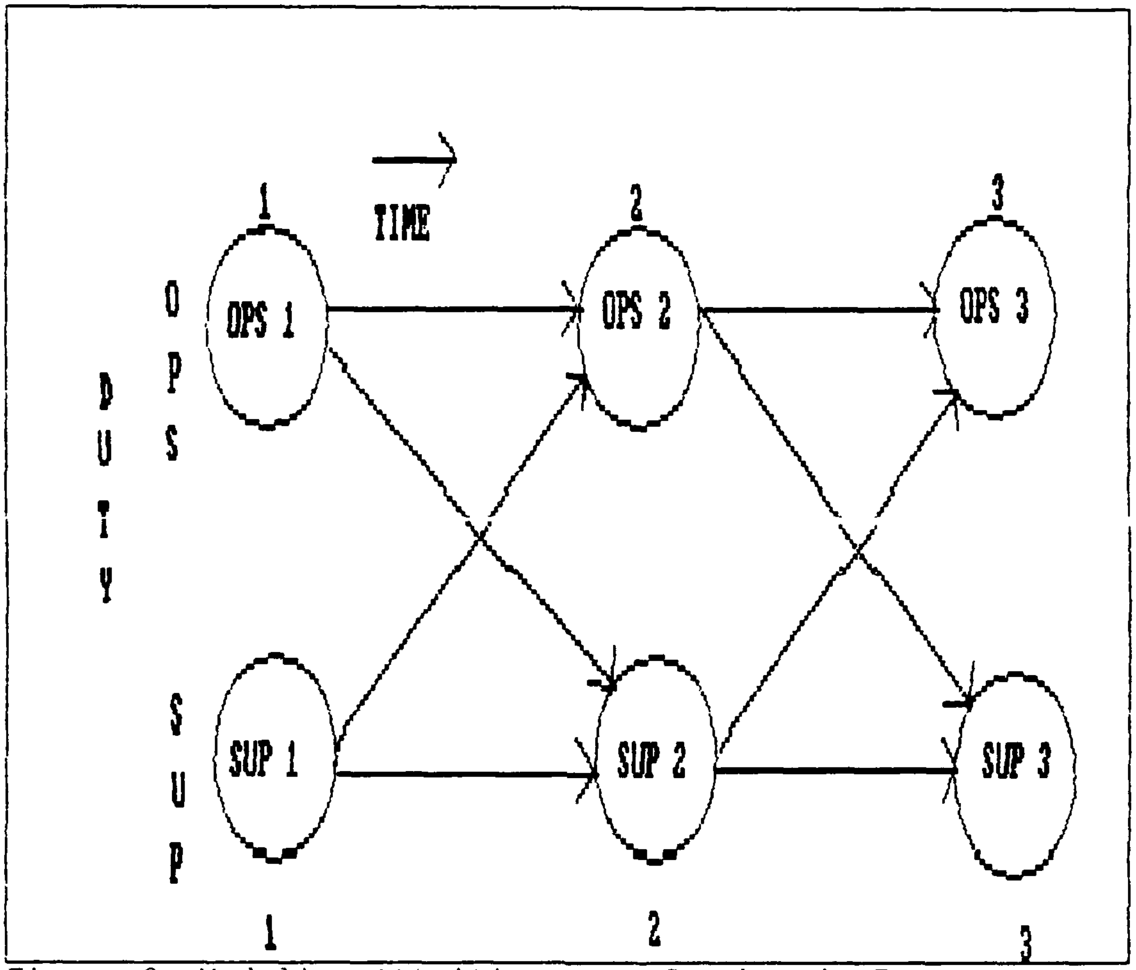


Figure 6 Modeling Attrition as a Stochastic Process

paths and it is possible that each of these three paths may result in a different attrition rate. Implementation of this type of formulation will require additional data support and research by AFMPC. Data which separates attrition rates based on what type of assignment preceded the current assignment will need to be provided. It will also require a rewrite of the existing FORTRAN code to incorporate this logic. Further research in this area might improve the

validity and usefulness of the current model.

An alternative to this approach would be to model retention as a function of gate credit versus ASD to calculate a percentage of time in flying duties. Different retention rates could be assigned to flows depending on what percentage of flying credit is associated with the flow.

Recommendations for Future Research

This section of the chapter contains several recommendations for future research. Each of these applications expand on the current network flow formulation.

New Weapon System Force Structure. One area of concern for resource managers at AFMPC is how to build and maintain the necessary rated force for a new weapon system. A case in point is the C-17 weapon system. Issues concerning experience level mixtures, rank structure, and proper manpower levels are all part of the overall problem. Another problem is where the necessary manpower to form the new weapon system should be obtained. Every individual released from the tactical airlift pool or strategic airlift pool reduces the losing weapon system's stock. How many individuals should be cross-trained from each weapon system and from what ASD year groups should these individuals come from?

To model the losses from the tactical or strategic airlift manpower systems, a new duty type and new nodes need to be

added to the existing network. The new duty type, call it "C17", represents those pilots who are assigned to the C-17. Once these pilots are assigned to the C-17, they never reenter the network. There will also be side constraints which contain the requirements, if any, for pilots in the duty type "C17". These side constraints can be built on a half-year basis and in ASD year group requirements. An example of a side constraint is a requirement for 5 pilots for duty type "C17" for 1990 (first half) and all of them to be from ASD year group 6. All the arcs leaving nodes identified with duty type "C17" will have 100% attrition. This will imitate the fact that once an individual is assigned to the C-17 weapon system, he/she never returns to the network.

Modeling the Dual-Track System. A proposed system which allows for a segment of the rated force to serve in only flying assignments is commonly referred to as the dual-track system. It is believed by many that the inclusion of this system would increase morale and retention among the rated force (9:30). There are many different ways to implement this policy but the results on the overall rated force is unknown. Of particular concern is how the pilots who are not in the "fly only" track will be affected. How many of these pilots will miss flight gates and how many will be forced to serve in back-to-back rated supplement

positions? These types of questions could be answered by the current network formulation if some changes were made to the network.

A fifth duty type, call it "FLY", could be created to represent those individuals who are in the fly-only track. Once an individual is placed into the fly-only track, he/she can not serve in any other duty type. Additional side constraints which limit the total number of pilots in the fly-only track could also be included. Some type of logic will need to be incorporated which distinguishes which individuals are selected for the fly-only track.

The changes listed in the previous paragraph are not exhaustive; there are perhaps other changes which are needed to completely model the dual-track system. However, this discussion does show that the basic network formulation is a solid base from which different dual-track systems can be evaluated.

Conclusion

The main objective of this research was to develop a model which accurately represents the rated force and also has the flexibility to represent how differing policies affect the system. To meet this objective, some sub-objectives were identified. These sub-objectives were concerned with producing useable output and identifying areas of research to which the basic network flow model could be applied.

Overall, the objectives of the research were satisfied. As discussed in the section on model shortcomings, there are some areas in which the model could be enhanced. These include alternative solution algorithms, evaluating various retention models, and modeling all 25 ASD year groups. In its present form, the network formulation can be used by AFMPC resource managers to evaluate current policies or proposed policies in light of their effects on the rated force structure. The identification of significant bottlenecks in the system and the flight gate distribution are just two examples of useful information provided by the package which help promote this evaluation process.

Finally, there are several real-world applications that this basic network flow model could help evaluate. Among the applications discussed in this study were the formation of a new weapon system and the analysis of different dual-track systems.

Appendix A: User's Guide

This guide contains basic instructions for running the computer programs that implement the rated force network model.

Computer System

The initial implementation of the model was developed on a Digital Equipment VAX 11/785 computer running the VMS operating system. The programs are coded in standard FORTRAN 77 although some modifications may be necessary prior to running on other computer systems.

MINOS version 5.0 was used to solve the resulting model.

Computer Files

Descriptions of the program's data and output files are provided in this section.

Program Files. The program subroutines, all written in FORTRAN 77, are as follows:

1. MPSIN - This is the subroutine which builds the MPS data file. It accomplishes the following tasks:

   a. Provides a means for inputting model parameters.

   b. Reads the rotation data file, "ROTE.DAT" (which must be built from the AFMPC data base).

   c. Performs the operations necessary to describe the basic network structure.

   d. Builds the required data files needed by MINOS. These files are the COLUMN section, ROWS section, and RHS section, and are in the standard MPS format.

2. INSERT - This subroutine converts the three sections built by MPSIN into the specific format required by MINOS.

3. OUTPUT - This is the subroutine which creates the various output files. It reads the MINOS raw output file (SOL.DAT) and converts it to information located in three separate output files, OUTPUT.DAT, CHART.DAT, and GATES.DAT.

4. SPECS.DAT - A separate specifications file is needed by MINOS to execute properly. For this study, this file is referred to as "SPECS.DAT". Appendix E contains a typical specifications file. For more information, refer to the MINOS 5.0 User's Guide.

Input Data File. A single input data file is required by the model. The subroutine MPSIN expects the file to be named "ROTE.DAT". The required FORTRAN format for each data line is (A4,2(I4),I3,8(I4)). The fields contain data as described below:

1. Current duty assignment (format A4).

a. "OPS" - flying duties, including advanced student duties and flying staff positions.

b. "SUP" - rated supplement and nonflying staff duties.

c. "AFIT" - Air Force Institute of Technology full-time graduate degree programs.

d. "PME" - resident professional military education.

2. Aviation Service Date (ASD) year group

(format I4), in tenths of years, as of the start time of the model horizon. Note that no decimal point should be used. Dividing the data file value by 10 will provide the number of years. As an example, a value of "105" would be used to represent 10 1/2 (10.5) years.

3. Flying gate credit accumulated. (format I4), in tenths of years, as of the start time of the model time horizon. Again, no decimal point is used.

4. The remaining nine fields (format I3,8(I4)) contain integer values representing the number of individuals (with characteristics described by the first three fields) that arrived at their current duty station within specific time periods. The first of these fields represents the number of individuals who arrived over 4 years prior to the start time of the model. The next column represents the number that arrived 3-1/2 to 4 years prior to model start time. Successive columns represent successively more recent half-year increments. The last field represents the number of individuals who arrived on station within the 6-month period immediately preceding the model start time.

Output Files. The subroutines MPSIN, INSERT, MINOS1, and OUTPUT produce several output files.

1. INPUT.DAT - This file is produced by MPSIN and is a presentation of the data found in ROTE.DAT.

2. ROWS.DAT, COLUMN.DAT, and RHS.DAT - These files are all produced by MPSIN and are an intermediate form of the data needed by MINOS. They are used as input by the subroutine INSERT and can be deleted anytime.

3. MPSIN.DAT - This file is created by the subroutine INSERT and contains data in the correct MPS format for use by MINOS.

4. SUM.DAT - This file is produced by MINOS and contains a brief summarization of the MINOS run. It contains the status of the solution for every iteration, the exit condition, and a summary of the final solution.

5. SOL.DAT - This file is produced by MINOS and contains the final solution found by MINOS. For information on this file, refer to the MINOS 5.0 User's Guide, page 70.

6. OUTPUT.DAT - This file is produced by subroutine OUTPUT and contains the "optimal" assignment

policy, the total number of missed flight gates, and the distribution of personnel within the duty types.

7. CHART.DAT - This file contains raw data which represents how each initial ASD year group changes as model time progresses. The SAS programs needed to convert this data to charts are described later in this guide.

8. GATES.DAT - This file contains raw data which represents the flight gate distribution of the rated force at some point in time. The SAS programs needed to convert this data to a chart are described later in this guide.

Running the Model

There are four steps in this process.

STEP 1 - Building the input file. The input file, "ROTE.DAT", consists of the information previously described. A separate SAS program to search the AFMPC data base and produce the required output was developed by AFMPC personnel and is reproduced below:

```
DATA;
SET SASDB.BWA (KEEP=AFF16 AFC180 AFC50 TYPIND ASGN1 APY20
PROJRC
    BUDCAT APZ AQA50 AKU19 ATJ AHB XOY CAT);
/* SELECT TAC ALFT PILOTS EXCLUDING ENROUTE & TRANSIENT */
IF TYPIND='02PLT' AND (ASGN1='A' OR ASGN1='B') AND
(SUBSTR(APY20,1,1)='H'
    OR SUBSTR(PROJRC,1,1)='H');
/* AGGREGATE BUDCATS INTO FLYING, NOFLYING AND SUPPLEMENT
CATEGORIES */
DUTY='     ';
DUTY=SUBSTR(BUDCAT,3,3);
IF DUTY='A/S' THEN DUTY='ADVSTU';
IF DUTY='STF' AND (APZ='3' OR APZ='4') THEN DUTY='NFSTF';
IF DUTY='STF' AND (APZ='6' OR APZ='8') THEN DUTY='FSTF';
IF AKU19='OK' AND ATJ='3' AND AHB='L' AND DUTY='SUP' THEN
DUTY='AFIT';
IF DUTY='FOR' OR DUTY='TRN' THEN DUTY='OPS';
IF DUTY='SUP' AND SUBSTR(XOY,2,4)='0003' OR CAT='ASTR' THEN
DUTY='PME';
IF DUTY='STF' AND APZ='0' THEN DUTY='SUP';
IF DUTY='STF' OR DUTY='UNK' THEN DELETE;
;
```

```
/*RECODES AVIATION SERVICE DATE INTO HALF YEAR INCREMTS
(X10)*/
IF '01APR88'D LE AFC180 LE '30SEP88'D THEN ASD=5;
IF '01OCT87'D LE AFC180 LE '31MAR88'D THEN ASD=10;
IF '01APR87'D LE AFC180 LE '30SEP87'D THEN ASD=15;
IF '01OCT86'D LE AFC180 LE '31MAR87'D THEN ASD=20;
IF '01APR86'D LE AFC180 LE '30SEP86'D THEN ASD=25;
IF '01OCT85'D LE AFC180 LE '31MAR86'D THEN ASD=30;
IF '01APR85'D LE AFC180 LE '30SEP85'D THEN ASD=35;
IF '01OCT84'D LE AFC180 LE '31MAR85'D THEN ASD=40;
IF '01APR84'D LE AFC180 LE '30SEP84'D THEN ASD=45;
IF '01OCT83'D LE AFC180 LE '31MAR84'D THEN ASD=50;
IF '01APR83'D LE AFC180 LE '30SEP83'D THEN ASD=55;
IF '01OCT82'D LE AFC180 LE '31MAR83'D THEN ASD=60;
IF '01APR82'D LE AFC180 LE '30SEP82'D THEN ASD=65;
IF '01OCT81'D LE AFC180 LE '31MAR82'D THEN ASD=70;
IF '01APR81'D LE AFC180 LE '30SEP81'D THEN ASD=75;
IF '01OCT80'D LE AFC180 LE '31MAR81'D THEN ASD=80;
IF '01APR80'D LE AFC180 LE '30SEP80'D THEN ASD=85;
IF '01OCT79'D LE AFC180 LE '31MAR80'D THEN ASD=90;
IF '01APR79'D LE AFC180 LE '30SEP79'D THEN ASD=95;
IF '01OCT78'D LE AFC180 LE '31MAR79'D THEN ASD=100;
IF '01APR78'D LE AFC180 LE '30SEP78'D THEN ASD=105;
IF '01OCT77'D LE AFC180 LE '31MAR78'D THEN ASD=110;
IF '01APR77'D LE AFC180 LE '30SEP77'D THEN ASD=115;
IF '01OCT76'D LE AFC180 LE '31MAR77'D THEN ASD=120;
IF '01APR76'D LE AFC180 LE '30SEP76'D THEN ASD=125;
IF '01OCT75'D LE AFC180 LE '31MAR76'D THEN ASD=130;
IF '01APR75'D LE AFC180 LE '30SEP75'D THEN ASD=135;
IF '01OCT74'D LE AFC180 LE '31MAR75'D THEN ASD=140;
IF '01APR74'D LE AFC180 LE '30SEP74'D THEN ASD=145;
IF '01OCT73'D LE AFC180 LE '31MAR74'D THEN ASD=150;
IF '01APR73'D LE AFC180 LE '30SEP73'D THEN ASD=155;
IF '01OCT72'D LE AFC180 LE '31MAR73'D THEN ASD=160;
IF '01APR72'D LE AFC180 LE '30SEP72'D THEN ASD=165;
IF '01OCT71'D LE AFC180 LE '31MAR72'D THEN ASD=170;
IF '01APR71'D LE AFC180 LE '30SEP71'D THEN ASD=175;
IF '01OCT70'D LE AFC180 LE '31MAR71'D THEN ASD=180;
IF '01APR70'D LE AFC180 LE '30SEP70'D THEN ASD=185;
IF AFC180 LE '31MAR70'D THEN ASD=190;
/*RECODES GATE TIME INTO HALF YEAR INCREMTS (X10)*/
IF DUTY='OPS' THEN DO;
IF 2 LE AFF16 LE 7 THEN FLYACCUM=5;
IF 8 LE AFF16 LE 13 THEN FLYACCUM=10;
IF 14 LE AFF16 LE 19 THEN FLYACCUM=15;
IF 20 LE AFF16 LE 25 THEN FLYACCUM=20;
IF 26 LE AFF16 LE 31 THEN FLYACCUM=25;
IF 32 LE AFF16 LE 37 THEN FLYACCUM=30;
IF 38 LE AFF16 LE 43 THEN FLYACCUM=35;
IF 44 LE AFF16 LE 49 THEN FLYACCUM=40;
```

```
IF 50 LE AFF16 LE 55 THEN FLYACCUM=45;
IF 56 LE AFF16 LE 61 THEN FLYACCUM=50;
IF 62 LE AFF16 LE 67 THEN FLYACCUM=55;
IF 68 LE AFF16 LE 73 THEN FLYACCUM=60;
IF 74 LE AFF16 LE 79 THEN FLYACCUM=65;
IF 80 LE AFF16 LE 85 THEN FLYACCUM=70;
IF 86 LE AFF16 LE 91 THEN FLYACCUM=75;
IF 92 LE AFF16 LE 97 THEN FLYACCUM=80;
IF 98 LE AFF16 LE 103 THEN FLYACCUM=85;
IF 104 LE AFF16 LE 109 THEN FLYACCUM=90;
IF 110 LE AFF16 LE 115 THEN FLYACCUM=95;
IF 116 LE AFF16 LE 121 THEN FLYACCUM=100;
IF 122 LE AFF16 LE 127 THEN FLYACCUM=105;
IF AFF16 GE 128 THEN FLYACCUM=110;
END;
IF (DUTY='AFIT' OR DUTY='PME' OR DUTY='SUP') THEN DO;
IF 6 LE AFF16 LE 11 THEN FLYACCUM=5;
IF 12 LE AFF16 LE 17 THEN FLYACCUM=10;
IF 18 LE AFF16 LE 23 THEN FLYACCUM=15;
IF 24 LE AFF16 LE 29 THEN FLYACCUM=20;
IF 30 LE AFF16 LE 35 THEN FLYACCUM=25;
IF 36 LE AFF16 LE 41 THEN FLYACCUM=30;
IF 42 LE AFF16 LE 47 THEN FLYACCUM=35;
IF 48 LE AFF16 LE 53 THEN FLYACCUM=40;
IF 54 LE AFF16 LE 59 THEN FLYACCUM=45;
IF 60 LE AFF16 LE 65 THEN FLYACCUM=50;
IF 66 LE AFF16 LE 71 THEN FLYACCUM=55;
IF 72 LE AFF16 LE 77 THEN FLYACCUM=60;
IF 78 LE AFF16 LE 83 THEN FLYACCUM=65;
IF 84 LE AFF16 LE 89 THEN FLYACCUM=70;
IF 90 LE AFF16 LE 95 THEN FLYACCUM=75;
IF 96 LE AFF16 LE 101 THEN FLYACCUM=80;
IF 102 LE AFF16 LE 107 THEN FLYACCUM=85;
IF 108 LE AFF16 LE 113 THEN FLYACCUM=90;
IF 114 LE AFF16 LE 119 THEN FLYACCUM=95;
IF 120 LE AFF16 LE 125 THEN FLYACCUM=100;
IF 126 LE AFF16 LE 131 THEN FLYACCUM=105;
IF AFF16 GE 132 THEN FLYACCUM=110;
END;
/*RECODES DATE ARR STATION TO CORRESPONDING VARIABLE FOR
SUMMARY*/
IF AFC50 LT '30SEP83'D THEN PRE_O83=1;
IF '01OCT83'D LE AFC50 LE '31MAR84'D THEN O83_M84=1;
IF '01APR84'D LE AFC50 LE '30SEP84'D THEN A84_S84=1;
IF '01OCT84'D LE AFC50 LE '31MAR85'D THEN O84_M85=1;
IF '01APR85'D LE AFC50 LE '30SEP85'D THEN A85_S85=1;
IF '01OCT85'D LE AFC50 LE '31MAR86'D THEN O85_M86=1;
IF '01APR86'D LE AFC50 LE '30SEP86'D THEN A86_S86=1;
IF '01OCT86'D LE AFC50 LE '31MAR87'D THEN O86_M87=1;
IF '01APR87'D LE AFC50 LE '30SEP87'D THEN A87_S87=1;
```

```
IF '01OCT87'D LE AFC50 LE '31MAR88'D THEN O87_M88=1;
IF '01APR88'D LE AFC50 LE '30SEP88'D THEN A88_NOW=1;
;
PROC SUMMARY NWAY;
  CLASS DUTY ASD FLYACCUM;
  VAR PRE_O83 O83_M84 A84_S84 O84_M85 A85_S85 O85_M86
A86_S86
      O86_M87 A87_S87 O87_M88 A88_NOW;
  OUTPUT OUT=SSD.OLSON SUM=;

PROC SORT; BY DUTY ASD FLYACCUM;
PROC PRINT;
  VAR DUTY ASD FLYACCUM PRE_O83 O83_M84 A84_S84 O84_M85
A85_S85
      O85_M86 A86_S86 O86_M87 A87_S87 O87_M88 A88_NOW;
  SUM  PRE_O83 O83_M84 A84_S84 O84_M85 A85_S85 O85_M86
A86_S86
       O86_M87 A87_S87 O87_M88 A88_NOW;
  TITLE 'DT ARR STA BASED ON DUTY TYPE, ASD, AND ACCUM GATE
TIME';
;
PROC CONTENTS;
RUN;
```

<u>STEP 2 - Initialize Parameters</u>. The subroutine MPSIN provides the means for adjusting parameters such as manning level requirements, retention rates, duty durations, and model run time. The information about manning requirements and about FAIP/UFT requirements are found in the Rated Management Document (RMD). To change a parameter, edit the appropriate line(s) of the program file. Internal program documentation should be sufficient to direct a personnel analyst to the appropriate line(s).

NOTE TO THE USER! Ensure that the input rotation data and the data from the Rated Management Document are from the same weapon system source. For example, if the weapon system to be modeled is Tactical Airlift pilots then the data from the RMD and from the AFMPC data base for Tactical Airlift pilots must be extracted. It is important that these two sources match.

NOTE TO THE USER! To change the number of ASD year groups to 25, the following changes need to be accomplished. Adjust all the array structures and parameter values to a value of 50 (25*2). Next, adjust the parameter which represents the number of ASD groups present in the formulation. This parameter is called NUMASD and should be set to 50. Finally, ensure that the output driver

subroutine is also adjusted to reflect the larger number of ASD year groups.

STEP 3 - Running MINOS. The steps below are designed for a system with MINOS 5.0 installed such that MINOS can accept a complied FORTRAN program.

a. Compile the FORTRAN program MPSIN.FOR. This program consists of a main program which performs call to the appropriate subroutines. The order of the subroutine calls is MPSIN, INSERT, MINOS1, and OUTPUT.

b. Create the specifications file, SPECS.DAT. This file is required by MINOS and must be built separately. The file below is an example of a specifications file. For additional information see the MINOS 5.0 User's Guide.

```
BEGIN RATED
   ROWS         12000
   COLUMNS      28000
   ELEMENTS     45200
   MPS FILE         9
   SUMMARY FILE  12
   SOLUTION FILE 13
   WORKSPACE(USER) 2000000
   WORKSPACE(TOTAL) 3000000
END RATED
```

c. At the system prompt, type MINOS. This should cause the system to recognize a request for a MINOS entry. The standard questions will then appear on the monitor. The following shows the questions which appear along with the appropriate answers that the user should make.

SPECS file (no default is permitted): SPECS.DAT
PRINT file [MINOSPRINT.LIS] (brackets indicate default value): PRINT.LIS

Compiled FORTRAN subroutine file [none]: MPSIN.OBJ

If you have made file assignments to unit numbers in your SPECS file and want to have the input or output come or go to a file not of the format FOR008.DAT, you must assign the unit number to the desired file name.

Enter unit number needing assignment (<RET> for none): 9
Enter file name: MPSIN1.DAT

```
Enter unit number needing assignment (<RET> for
none): 12
Enter file name: SUM.DAT

Enter unit number needing assignment (<RET> for
none): 13
Enter file name: SOL.DAT

Enter unit number needing assignment (<RET> for
none):

Should this be run (I)nteractively or (B)atch
(I or [B])? B

(At this point, there will be a question concerning
 what queue to use).
```

Note that the user responds with MPSIN.OBJ to the second question. This will cause MINOS to create and execute the program file MPSIN.EXE. Remember that this program consists of a series of calls to subroutines. MINOS will execute each of the subroutines in turn. Also note that the job is run in the batch mode. This is necessary because the normal run time can easily exceed 100,000 CPU seconds.

STEP 4 - Developing the Output. The final step is to develop and analyze the output. The file OUTPUT.DAT is complete in itself and contains the information described previously. The file CHART.DAT contains raw data and the following SAS programs must be run in order to convert the raw data to the desired charts:

```
 FILENAME NEW 'CHART.DAT';
 FILENAME OUT 'CONVERT.DAT';
DATA NEW;
INFILE NEW;
FILE OUT;
 INPUT NUMBER @;
 IF NUMBER>0 THEN DO;
    IF NUMBER<.5 THEN NUMBER=0;
    INPUT TIME $ DUTY $ ASDYG $;
    DO I =1 TO NUMBER;
    PUT TIME DUTY ASDYG;
     OUTPUT;
    END;

FILENAME NEW 'CONVERT.DAT';
```

```
DATA NEW;
INFILE NEW;
INPUT TIME $ DUTY $ ASDYG $;
PROC SORT DATA=NEW;
BY ASDYG;
 PROC CHART DATA=NEW;
 BY ASDYG;
 VBAR TIME/SUBGROUP=DUTY;
```

These two SAS programs will convert the raw data to actual charts of every ASD year group as it changes over time.

The file GATES.DAT also contains raw data which requires corresponding SAS programs to convert the data. These are listed below:

```
FILENAME NEW 'GATES.DAT';
DATA NEW;
INFILE NEW;
INPUT NUMBER TAFSCD $ GATE $;
PROC CHART DATA=NEW;
  VBAR TAFSCD/MISSING SUMVAR=NUMBER SUBGROUP=GATE;
```

ADDING SIDE CONSTRAINTS.

To add side constraints, such as manning level constraints or experience level constraints, the user should follow the steps listed below.

STEP 1. A constraint number must be added to the ROWS section of the MPS file. The user must add to the appropriate FORTRAN code in the ROWS section in order to accomplish this.

STEP 2. The user must determine which flows contribute to the constraint just added. Once these flow numbers have been determined each of them must contain the constraint number (row number) and how much they contribute to the constraint. For example if flow number 20 (labeled X20) contributes to the constraint then the entry in the COLUMNS section of the MPS file would look like the following:

```
X20    N01   1.0
```

where N01 is the appropriate constraint number;
1.0 is how much X20 contributes to the constraint.

STEP 3. Finally, the user must add an entry to the

RHS section of the MPS section. This is done in the FORTRAN section labled RHS.

APPENDIX B

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C
C     PROGRAM MAIN
C     THIS PROGRAM WILL FIRST CALL THE SUBROUTINE MPSIN.  MPSIN
C     BUILDS THE MPS INPUT FILE NEEDED BY MINOS.
C     MINOS IS THEN CALLED AND AN OPTIMAL SOLUTION IS STORED IN
C     SOL.DAT
C     THE FILE SOL.DAT IS USED BY THE SUBROUTINE OUTPUT WHICH
C     BUILDS USEABLE OUTPUT FILES
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C
      PROGRAM MAIN
      COMMON/FIRST/MAXNOD,MAXFLOW,RQMT,FLOW,ATR,ASDSUM,MODTIME
      COMMON/FIRST/FAIP
      DOUBLE PRECISION Z(3000000)
      DATA NWCORE/3000000/
C
      CALL MPSIN
C
C     THE SUBROUTINE INSERT FORMATES THE DATA FROM MPSIN INTO
C     THE NECESSARY FORMAT REQUIRED BY MINOS.  THE FINAL DATA
C     FILE IS CALLED MPSIN.DAT
C
      CALL INSERT
C
C     MINOS USES THE DATA FOUND IN MPSIN.DAT AND THE
C     SPECIFICATIONS FOUND IN SPECS.DAT
C
      CALL MINOS1(Z,NWCORE)
      CLOSE (UNIT=13)
C
C     MINOS CREATES SEVERAL DIFFERENT OUTPUT FILES.  THE FILE
C     SUM.DAT (SPECIFIED BY USER IN SPECS.DAT) CONTAINS A BRIEF
C     SUMMARY OF THE MINOS RUN.  IT CONTAINS NUMBER OF
C     ITERATIONS, VALUE OF THE OBJECTIVE FUNCTION, AND
C     WHETHER THE RUN WAS FEASIBLE.
C
C     SOL.DAT (SPECIFIED BY USER IN SPECS.DAT) CONTAINS THE
C     ACTUAL OPTIMAL SOLUTION FOUND.  IT IS IN A VERY SPECIFIC
C     FORMAT AND IS USED BY THE SUBROUTINE OUTPUT.
C
      CALL OUTPUT
C
C     OUTPUT CREATES TWO SEPERATE OUTPUT FILES WHICH CONTAIN
```

```
C      INFORMATION ABOUT THE OPTIMAL SOLUTION.  THE FIRST,
C      OUTPUT.DAT,DESCRIBES THE OPTIMAL ASSIGNMENTS, HOW MANY
C      FLIGHT GATES WERE MISSED, AND THE DISTRIBUTION OF MANNING
C      LEVELS.  THE SECOND FILE, CHART.DAT, CONTAINS THE RAW DATA
C      DESCRIBING HOW AN ENTERING ASD YEAR GROUP CHANGES
C      CHARACTERISTICS OVER TIME.  THIS FILE MUST BE INPUT TO THE
C      APPROPRIATE SAS PROGRAMS.
C
       STOP
       END
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C      SUBROUTINE MPS
C      THIS PROGRAM WILL BUILD THE INPUT MPS FILE WHICH IS
C      USED BY THE SOFTWARE PACKAGE MINOS
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C
       SUBROUTINE MPSIN
C
       COMMON/FIRST/MAXNOD,MAXFLOW,RQMT,FLOW,ATR,ASDSUM,MODTIME
       COMMON/FIRST/FAIP
       INTEGER ARCOST,ASDYG,ASDCK,ASDTEN,COUNT1,COUNT2
       INTEGER BEGNOD,COUNT,CYCLE,DEVVAR,DUR,DUTY,ENDDUT,ENDNOD
       INTEGER ENDTIM,FLAG,FLAG1,FLAG2,FLAG3,FLOWNUM,FLYCK,FLYCRE
       INTEGER GATETEN,MAXFLY,MAXFLOW,MAXNOD,MODTIME,MINFLY
       INTEGER NEWASD,NEWFLY,NODNUM,NUMASD,TEMPMAN
       INTEGER TIME,TNODNUM,TYPE
C
C
       INTEGER MANNING(1:20)
C
       INTEGER DUTDUR(1:4)
C
       INTEGER FY(1:10)
C
       INTEGER SUMTOS(1:9)
       INTEGER ASDGRP(1:20),DAS(1:20),FAIP(1:20)
       INTEGER FAILG1(1:9),FAILG2(1:9),FAILG3(1:9),FLYACC(1:22)
       INTEGER ROTE(1:20),UFT(1:20)
C
       INTEGER COST(1:3,1:3)
C
       INTEGER MANCON(1:20,1:4),RQMT(1:20,1:4)
       INTEGER AFIT(1:20),OPSLEN(1:3),SUPLEN(1:3)
       REAL STRUCT(1:21,1:2)
C
C
```

```
C      NODE IS DIMENSIONED FOR THE NUMBER OF TIME PERIODS, DUTY
C      TYPES ,ASD YEAR GROUPS (IN HALF YEAR INCREMENTS), AND
C      FLLYING CREDIT (IN HALF YEAR INCREMENTS).
C
       INTEGER NODE(1:20,1:4,0:42,0:22,0:1)
C
       INTEGER FLOW(1:60000,1:13)
C
       REAL EXTFLO,RCOST,RHS,TEMPATR,TEXTFLO,TRHS,WEIGH
C
       REAL ATR(1:20,0:42),ATRNUM(60000)
       REAL SUMDAS(1:4),GTDUT(1:4)
       REAL ASDPCT(1:4,0:42),ASDSUM(1:4,0:36),DUTPCT(1:4,0:42)
       REAL ADJUST(1:20,1:4)
       REAL ROTBYA(1:20,0:42)
       REAL TOTASD(0:42),GTROTE(1:10),DASBYA(1:9,1:4,0:42)
       REAL FLYPCT(0:42,0:22),FLYTOT(0:42,0:22),TOTDAS(1:9,1:4)
       REAL TOTROT(1:20,1:4,0:42)
       REAL WEIGHT(1:5)
       CHARACTER*4 CURDUTY
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C      THIS SECTION SPECIFIES MODEL PARAMETERS
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C      INPUT THE TOTAL TIME PERIOD THAT THE MODEL WILL RUN
C        1 = HALF YEAR
C        2 = ONE YEAR
C          .
C
C        9 = 4 1/2 YEARS
C       10 = 5 YEARS
C           ETC.
C
C      THE PRESENT CODE ONLY ALLOWS FOR A MAXIMUM OF 10 YEARS
C      (MODTIME=20)
C
C
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C      REMEMBER IF A CHANGE IS MADE TO THE MODEL RUN TIME,
C      ADDITIONAL PARAMETERS FOR MANNING REQUIREMENTS MUST ALSO BE
C      INPUT!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
       MODTIME=14
C
C      INPUT THE NUMBER OF ASD YEAR GROUPS BEING USED
C
```

```
      NUMASD=42
C
C     INPUT THE FISCAL YEARS THAT THE MODEL USES
C
      FY(1)=88
      DO 5 I=1,(MODTIME/2)-1
      FY(I+1)=FY(1)+I
 5    CONTINUE
C
C
C     INPUT THE VALUES FOR STRUCT
C     THIS ARRAY HOLDS THE DESIRED PERCENTAGES THAT THE USER
C     WANTS AT THE END OF THE MODEL RUN.
C     THE ARRAY STRUCT HAS TWO DIMENSIONS:  ASD YEAR GROUP
C                                           DUTY TYPE
C     WHERE DUTY TYPE IS EITHER OPERATIONAL FLYING (1) OR OTHER
C     (2).
C
      STRUCT(1,1)=1.0
      STRUCT(1,2)=0.0
      STRUCT(2,1)=1.0
      STRUCT(2,2)=0.0
      STRUCT(3,1)=1.0
      STRUCT(3,2)=0.0
      STRUCT(4,1)=1.0
      STRUCT(4,2)=0.0
      STRUCT(5,1)=1.0
      STRUCT(5,2)=0.0
      STRUCT(6,1)=1.0
      STRUCT(6,2)=0.0
      STRUCT(7,1)=1.0
      STRUCT(7,2)=0.0
      STRUCT(8,1)=.8
      STRUCT(8,2)=.2
      STRUCT(9,1)=.8
      STRUCT(9,2)=.2
      STRUCT(10,1)=.7
      STRUCT(10,2)=.3
      STRUCT(11,1)=.7
      STRUCT(11,2)=.3
      STRUCT(12,1)=.6
      STRUCT(12,2)=.4
      STRUCT(13,1)=.6
      STRUCT(13,2)=.4
      STRUCT(14,1)=.65
      STRUCT(14,2)=.35
      STRUCT(15,1)=.65
      STRUCT(15,2)=.65
      STRUCT(16,1)=.7
      STRUCT(16,2)=.3
```

```
      STRUCT(17,1)=.8
      STRUCT(17,2)=.2
      STRUCT(18,1)=.85
      STRUCT(18,2)=.15
      STRUCT(19,1)=.9
      STRUCT(19,2)=.1
      STRUCT(20,1)=.9
      STRUCT(20,2)=.1
      STRUCT(21,1)=.95
      STRUCT(21,2)=.05
C
C     INPUT THE WEIGHTS FOR THE DEVIATION VARIABLES ASSOCIATED
C     WITH THE MANNING CONSTRAINTS.  THERE ARE FOUR DUTY TYPES
C     SO THERE ARE FOUR WEIGHTS NEEDED.  THE ARRAY WEIGHT HOLDS
C     THESE VALUES.  WEIGHT(1) IS THE WEIGHT ASSOCIATED WITH
C     THE DEVIATION VARIABLES FOR DUTY TYPE "OPS".  WEIGHT(2) IS
C     ASSOCIATED WITH THE DEVIATION VARIABLE FOR DUTY TYPE "SUP".
C     WEIGHT(3) IS ASSOCIATED WITH DUTY TYPE "AFIT" AND
C     WEIGHT(4) IS ASSOCIATED WITH DUTY TYPE "PME".
C
      WEIGHT(1)=.8
      WEIGHT(2)=.23
      WEIGHT(3)=.23
      WEIGHT(4)=1.0
C
C     INPUT THE WEIGHT FOR THE DEVIATION VARIABLES ASSOCIATED
C     WITH THE ENDING FORCE CONDITIONS.
C
      WEIGHT(5)=1.0
C
C     INPUT THE VALUES FOR OPSLEN AND SUPLEN.  THESE ARRAYS HOLD
C     THE THREE DIFFERENT DUTY DURATIONS FOR OPS AND SUP
C     ASSIGNMENTS. (INPUT IN HALF YEAR INCREMENTS)
C
      OPSLEN(1)=8
      SUPLEN(1)=8
C
C     IN CONJUCTION WITH THE ARRAYS OPSLEN AND SUPLEN THE USER
C     MUST ALSO INPUT THE NUMBER OF DIFFERENT DUTY DURATIONS FOR
C     EACH OF THESE.
C
      CYCLE=1
C
C     PROJECTED UFT GAINS:  ASSUMPTION IS ENTRY AT ONE YEAR ASD
C     GROUP AND ONE YEAR FLYING CREDIT.  FISCAL YEAR TOTALS FROM
C     THE RATED MANAGEMENT DOCUMENT ARE DIVIDED IN HALF TO GIVE
C     THE APPROPRIATE HALF YEAR TOTALS
C
      UFT(1)=50
      UFT(2)=51
```

```
      UFT(3)=66
      UFT(4)=67
      UFT(5)=69
      UFT(6)=69
      UFT(7)=69
      UFT(8)=69
      UFT(9)=69
      UFT(10)=69
      UFT(11)=69
      UFT(12)=69
      UFT(13)=69
      UFT(14)=69
C
C     PROJECTED FAIP/OTHER GAINS:  ASSUMPTION IS ENTRY AT 4 YEAR

C     ASD GROUP AND 4 YEAR FLYING CREDIT. FISCAL YEAR QUANTITIES
C     FROM THE RATED MANAGEMENT DOCUMENT ARE DIVIDED IN HALF.  IT
C     IS ASSUMED THAT THESE VALUES ARE ALREADY ADJUSTED FOR
C     ATTRITION.
C
      FAIP(1)=24
      FAIP(2)=25
      FAIP(3)=21
      FAIP(4)=22
      FAIP(5)=22
      FAIP(6)=22
      FAIP(7)=22
      FAIP(8)=22
      FAIP(9)=22
      FAIP(10)=22
      FAIP(11)=22
      FAIP(12)=22
      FAIP(13)=22
      FAIP(14)=22
C
C     TOTAL UFT AND FAIP/OTHER GAINS
C     THESE GAINS WILL ENTER THE NETWORK AT THE FOLLOWING NODES:
C           UFT WILL ENTER AT DUTY 1, ASDYG 2 AND FLYCRE 2.
C           FAIP WILL ENTER AT DUTY 1, ASDYG 8 AND ASDYG 8.
C     THESE ACCESSIONS ARE MODELED AS POSITIVE EXTERNAL FLOWS
C     INTO THE NETWORK
C
      DO 10 TIME=1,MODTIME
         NODE(TIME,1,2,2,1)=UFT(TIME)
         NODE(TIME,1,8,8,1)=FAIP(TIME)
 10   CONTINUE
C
C     MANNING REQUIREMENTS FOR EVERY HALF YEAR (FISCAL YEAR
C     REQUIREMENTS DIVIDED IN HALF).  THESE NUMBERS WILL BE
C     USED AS RHS ARGUMENTS FOR THE MANNING LEVEL CONSTRAINTS
```

```
C
C
C     FLYING POSITIONS
C     NOTE:  THIS IS THE SUM OF "FORCE" + "TRAINING" +
C     "ADVANCED STUDENT" + "ATC MWS PRESENSE" FROM THE
C     RATED MANAGEMENT DOCUMENT
C
      RQMT(1,1)=1710
      RQMT(2,1)=1710
      RQMT(3,1)=1499
      RQMT(4,1)=1499
      RQMT(5,1)=1546
      RQMT(6,1)=1546
      RQMT(7,1)=1588
      RQMT(8,1)=1588
      RQMT(9,1)=1596
      RQMT(10,1)=1596
      RQMT(11,1)=1596
      RQMT(12,1)=1596
      RQMT(13,1)=1596
      RQMT(14,1)=1596
C
C     RATED STAFF/SUPPLEMENT POSITIONS (NONFLYING)
C     NOTE:  THIS IS THE SUM OF "STAFF" + "GENERAL OPS STAFF" +
C     "SUPPLEMENT" FROM THE RATED MANAGEMENT DOCUMENT.
C
      RQMT(1,2)=1051
      RQMT(2,2)=1051
      RQMT(3,2)=1041
      RQMT(4,2)=1041
      RQMT(5,2)=1038
      RQMT(6,2)=1038
      RQMT(7,2)=930
      RQMT(8,2)=930
      RQMT(9,2)=924
      RQMT(10,2)=924
      RQMT(11,2)=924
      RQMT(12,2)=924
      RQMT(13,2)=924
      RQMT(14,2)=924
C
C     AFIT POSITIONS (NONFLYING)
C     NOTE:  THE RMD GROUPS AFIT AND PME TOGETHER.
C     IN THIS MODEL, THE REQUIREMENTS HAVE BEEN SPLIT
C     50-50 BETWEEN AFIT AND PME.
C
      RQMT(1,3)=33
      RQMT(2,3)=33
      RQMT(3,3)=33
      RQMT(4,3)=33
```

```
      RQMT(5,3)=33
      RQMT(6,3)=33
      RQMT(7,3)=29
      RQMT(8,3)=29
      RQMT(9,3)=29
      RQMT(10,3)=29
      RQMT(11,3)=29
      RQMT(12,3)=29
      RQMT(13,3)=29
      RQMT(14,3)=29
C
C     PME POSITIONS (NONFLYING)
C
      RQMT(1,4)=34
      RQMT(2,4)=34
      RQMT(3,4)=34
      RQMT(4,4)=34
      RQMT(5,4)=34
      RQMT(6,4)=34
      RQMT(7,4)=30
      RQMT(8,4)=30
      RQMT(9,4)=30
      RQMT(10,4)=30
      RQMT(11,4)=30
      RQMT(12,4)=30
      RQMT(13,4)=30
      RQMT(14,4)=30
C
C     INITIALIZE THE ARRAY ATR
C     THIS ARRAY CONTAINS THE ATTRITION RATES FOR EACH TIME
C     PERIOD/ASD COMBINATION
C
      DO 17 TIME=1,MODTIME
         ATR(TIME,0)=1.00
      ATR(TIME,1)=1.00
      ATR(TIME,2)=1.00
      ATR(TIME,3)=1.00
      ATR(TIME,4)=1.00
      ATR(TIME,5)=1.00
      ATR(TIME,6)=1.00
      ATR(TIME,7)=1.00
      ATR(TIME,8)=1.00
      ATR(TIME,9)=1.00
      ATR(TIME,10)=1.00
      ATR(TIME,11)=1.00
      ATR(TIME,12)=1.00
      ATR(TIME,13)=.8224
      ATR(TIME,14)=.8224
      ATR(TIME,15)=.9208
      ATR(TIME,16)=.9298
```

```
      ATR(TIME,17)=.8806
      ATR(TIME,18)=.8806
      ATR(TIME,19)=.8846
      ATR(TIME,20)=.8846
      ATR(TIME,21)=.92
      ATR(TIME,22)=.92
      ATR(TIME,23)=.9725
      ATR(TIME,24)=.9725
      ATR(TIME,25)=.9741
      ATR(TIME,26)=.9741
      ATR(TIME,27)=.9748
      ATR(TIME,28)=.9748
      ATR(TIME,29)=.9655
      ATR(TIME,30)=.9655
      ATR(TIME,31)=.965
      ATR(TIME,32)=.965
      ATR(TIME,33)=.9725
      ATR(TIME,34)=.9725
      ATR(TIME,35)=.9042
      ATR(TIME,36)=.9042
      ATR(TIME,37)=.6815
      ATR(TIME,38)=.6815
      ATR(TIME,39)=.7
      ATR(TIME,40)=.7
C
C        ASD YEAR GROUP 21 AND OVER ARE ALL GROUPED TOGETHER IN
C        ORDER TO REDUCE THE SIZE OF THE NETWORK
C
         ATR(TIME,41)=.7
         ATR(TIME,42)=.7
 17   CONTINUE
C
C
C     INITIALIZE THE ARRAY DUTDUR.  THIS ARRAY HOLDS THE
C     DURATION OF EACH TYPE OF DUTY ASSIGNMENT (IN HALF
C     YEAR INCREMENTS)
C     FOR DUTY TYPE 1 AND DUTY TYPE 2 (OPS AND SUP) THESE
C     DUTY DURATIONS ARE ONLU USED TO DETERMINE WHEN TO
C     CYCLE INTO THE NETWORK THE EXISTING INDIVIDUALS.
C     THE ARRAYS OPSLEN AND SUPLEN ARE USED LATER WHEN
C     DEVELOPING THE FEASIBLE FLOWS FROM NODES.
C
      DUTDUR(1)=8
      DUTDUR(2)=8
      DUTDUR(3)=3
      DUTDUR(4)=2
C
C     INITIALIZE THE ARRAY COST
C     COST(i,1) ASSIGNED FOR FAILURE TO MEET THE FLYING
C     GATE LOCATED IN COST(i,3) BY THE ASD YEAR FOUND IN
```

```
C       COST(i,2)
C
        COST(1,1)=8
        COST(1,2)=24
        COST(1,3)=12
        COST(2,1)=2
        COST(2,2)=36
        COST(2,3)=18
        COST(3,1)=1
        COST(3,2)=36
        COST(3,3)=22
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C       SECTION INPUT
C       THIS SECTION WILL INPUT THE ROTATION DATA FROM THE
C       APPROPTIATE DATA FILE.  THE DATA IS LOCATED IN TAC.DAT AND
C       WAS PROVIDED BY AFMPC.
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C
        OPEN(UNIT=4,FILE='TAC.DAT',STATUS='OLD')
        OPEN(UNIT=7,FILE='INPUT.DAT',STATUS='NEW')
C
C       START THE LOOP WHICH READS THE DATA FROM TAC.DAT
C
 20     CONTINUE
C
C       INTIALIZE PARAMETERS
C
        DO 21 I=1,9
           DAS(I)=0
 21     CONTINUE
        DO 22 TIME=1,15
           ROTE(TIME)=0
 22     CONTINUE
C
        READ(4,536,END=41)CURDUTY,ASDTEN,GATETEN,DAS(9),DAS(8),
       +DAS(7),DAS(6),DAS(5),DAS(4),DAS(3),DAS(2),DAS(1)
C
C       EACH RECORD IN THE FILE IS FORMATTED AS FOLLOWS:
C       THE FIRST FIELD IS THE DUTY TYPE (OPS,SUP,PME,AFIT)
C       THE SECOND FIELD IS THE ASD IN TENTHS OF YEARS
C       THE THIRD FIELD IS THE FLYING CREDIT IN TENTHS OF YEARS
C       THE NEXT NINE FIELDS CONTAIN THE NUMBER OF INDIVIDUALS
C       WHICH ARRIVED AT THEIR CURRENT DUTY STATION AT SOME
C       POINT IN TIME.  FOR EXAMPLE, DAS(9) CONTAINS THE # OF
C       INDIVIDUALS WHO ARRIVED OVER 4 YEARS AGO, DAS(8) CONTAINS
C       THE NUMBER WHO ARRIVED BETWEEN 3.5 - 4 YEARS AGO AND SO ON.
```

```
C
C
C     CONVERT DUTY TYPE FROM CHARACTER TO INTEGER
C
      IF(CURDUTY.EQ.'OPS ') DUTY=1
      IF(CURDUTY.EQ.'SUP ')DUTY=2
      IF(CURDUTY.EQ.'AFIT') DUTY=3
      IF(CURDUTY.EQ.'PME ') DUTY=4
C
C     IN THE VARIABLE DUTDUR(DUTY) IS THE AVERAGE TIME-ON-STATION

C     FOR EACH DUTY TYPE
C
      DUR=DUTDUR(DUTY)
C
C     IF THE NUMBER OF TIME PERIODS SINCE DATE ARRIVED STATION
C     (DAS) IS GREATER THAN OR EQUAL TO THE MODELED DURATION FOR
C     THE PARTICULAR DUTY TYPE, THEN THE INDIVIDUALS ARE ASSUMED
C     TO ROTATE IN TIME PERIOD ONE (FIRST HALF YEAR).  OTHERWISE,
C     THEY ARE ASSUMED TO ROTATE 'DUTDUR' TIME PERIODS AFTER DAS.
C
      J=0
C
C     THIS SECTION CALCULATES HOW MANY INDIVIDUALS ROTATE DURING
C     THE FIRST TIME PERIOD.
C
      DO 30 I=DUR+1,9
         J=J+1
         ROTE(1)=ROTE(1)+DAS(I)
 30   CONTINUE
C
C     THIS SECTION CALCULATES AT WHAT TIME PERIOD THE REMAINDER
C     OF THE INDIVIDUALS ROTATE.
C
      IF(J.EQ.0)J=1
      J=I-J-1
      DO 31 TIME=2,DUR+1
         IF(J.GT.0.AND.J.LT.10) THEN
            ROTE(TIME)=DAS(J)
         ELSE
            ROTE(TIME)=0
         ENDIF
         J=J-1
 31   CONTINUE
C
C     CONVERT ASD YEAR GROUP FROM TENTHS OF YEARS TO HALF YEAR
C     INCREMENTS
C
      ASDYG=(ASDTEN*2)/10
C
```

```
C     CONVERT FLYING CREDIT FROM TENTHS OF YEARS TO HALF YEAR
C     INCREMENTS
C
      FLYCRE=(GATETEN*2/10)
C
C     ACCUMULATE DAS FIGURES
C
      DO 32 I=1,9
         TOTDAS(I,DUTY)=TOTDAS(I,DUTY)+DAS(I)
         DASBYA(I,DUTY,ASDYG)=DASBYA(I,DUTY,ASDYG)+DAS(I)
 32   CONTINUE
C
C     ACCUMULATE TOTAL ROTATIONS BY TIME AND DUTY TYPE AND ASD
C     GROUP (BASED ON INITIAL ASD GROUP).
C     THESE ARE USED TO ADJUST THE MANNING REQUIREMENTS THAT
C     ARE USED AS SIDE CONSTRAINTS.
C     NOTE THAT THESE NUMBERS DO NOT INCLUDE UFT AND FAIP/OTHER
C     GAINS
C
      IF(ASDYG.GT.NUMASD) ASDYG=NUMASD
      DO 33 TIME=1,15
         GTROTE(TIME)=GTROTE(TIME)+ROTE(TIME)
       TOTROT(TIME,DUTY,ASDYG)=
     +   TOTROT(TIME,DUTY,ASDYG)+ROTE(TIME)
 33   CONTINUE
C
C     ADJUST DOWNSTREAM ASD YEAR GROUP
C
      ASDGRP(1)=ASDYG
      DO 34 TIME=2,9
         ASDGRP(TIME)=ASDGRP(TIME-1)+1
 34   CONTINUE
C
C
C     FORCE MINIMUM FLYING CREDIT TO BE ASD YEAR GROUP OR 6
C     YEARS, WHICHEVER IS LESS.
C
      IF(ASDYG.GE.12.AND.FLYCRE.LT.12) FLYCRE=12
C
C     FORCE FLYING CREDIT SO THAT IT IS NOT LARGER THAT ASDYG
C
      IF(FLYCRE.GT.ASDYG)FLYCRE=ASDYG
C
C     FORCE ALL ROTATIONS FOR ASD GROUP LT 6 YEARS TO BE FROM
C     FLYING JOBS
C
      IF(ASDYG.LT.12) THEN
         FLYCRE=ASDYG
         DUTY=1
      ENDIF
```

```
C
C     FORCE INDIVIDUALS CURRENTLY IN AFIT POSITIONS WITH ASD
C     GROUP GREATER THAN 13 TO ENTER THE NETWORK AT DUTY TYPE 2
C     (SUP) BECAUSE AFIT NODES DO NOT EXIST IN THE NETWORK FOR
C     THESE ASDS.
C
      DO 35 I=1,9
         IF(DUTY.EQ.3.AND.ASDGRP(I).GT.26) DUTY=2
C
C     FORCE INDIVIDUALS CURRENTLY IN PME POSITONS WITH ASD GROUPS
C     BETWEEN 8 AND 13 OR BETWEEN 15 AND 18 TO ENTER THE NETWORK
C     AT DUTY TYPE 2 ALSO.
C
         IF(DUTY.EQ.4) THEN
            IF(ASDGRP(I).LT.14) DUTY=2
            IF(ASDGRP(I).GT.16.AND.ASDGRP(I).LT.26) DUTY=2
            IF(ASDGRP(I).GT.30.AND.ASDGRP(I).LT.36) DUTY=2
         ENDIF
 35    CONTINUE
C
C     ADJUST DOWNSTREAM ACCUMULATED FLY CREDIT FOR FLYING DUTIES
C
      DO 36 TIME=1,9
         IF(DUTY.EQ.1) THEN
            FLYACC(TIME)=FLYCRE+TIME-1
         ELSE
            FLYACC(TIME)=FLYCRE
         ENDIF
 36   CONTINUE
C
C     FORCE MAXIMUM FLYING CREDIT TO BE 11 YEARS
C
      DO 37 TIME=1,9
         IF(FLYACC(TIME).GT.22) FLYACC(TIME)=22
 37   CONTINUE
C
C     TOTAL INITIAL PERSONNEL BY ASD YEAR GROUP/FLY CREDIT
C
      DO 38 TIME=1,9
         FLYTOT(ASDYG,FLYCRE)=FLYTOT(ASDYG,FLYCRE)+ROTE(TIME)
 38   CONTINUE
C
C     TOTAL INDIVIDUALS WHO WILL ALREADY HAVE FAILED TO MEET A
C     GATE AT THE TIME OF THEIR FIRST ROTATION INTO THE NETWORK

      DO 39 I=1,9
         IF(FLYACC(I).LT.12.AND.ASDGRP(I).GE.24)
     +   FAILG1(I)=FAILG1(I)+ROTE(I)
         IF(FLYACC(I).GT.12.AND.FLYACC(I).LT.18.AND.
     +   ASDGRP(I).GE.36) FAILG2(I)=FAILG2(I)+ROTE(I)
```

```
          IF(FLYACC(I).Gt.18.AND.FLYACC(I).LT.22.AND.
     +    ASDGRP(I).GE.36) FAILG3(I)=FAILG3(I)+ROTE(I)
 39    CONTINUE
C
C      PLACE EXTERNAL FLOW VALUES INTO NODE ARRAY.  VALUES ARE
C      ADDED TO EXISTING ENTRIES BECAUSE ABOVE CONVERSIONS OF
C      FLYCRE AND DUTY TYPE COULD RESULT IN MORE THAN ONE LINE
C      OF THE DATA FILE SUPPLING VALUES TO A SINGLE ARRAY (NODE)
C      LOCATION, AND BECAUSE ROTATING INDIVIDUALS MUST BE ADDED
C      TO UFT AND FAIP/OTHER GAINS WHICH ARE ALREADY IN 'NODE'.
C
       DO 40 I=1,9
          NODE(I,DUTY,ASDGRP(I),FLYACC(I),1)=ROTE(I)+
     +    NODE(I,DUTY,ASDGRP(I),FLYACC(I),1)
 40    CONTINUE
       GOTO 20
 41    CONTINUE
C
C      THIS SECTION WILL WRITE TO THE FILE 'INPUT.DAT' SOME
C      INFORMATION COMPILED ABOUT THE INPUT DATA
C
       WRITE(7,800)
       WRITE(7,801)DUTDUR(1)/2,DUTDUR(2)/2,DUTDUR(3)/2,
     + DUTDUR(4)/2
C
C      SUM ROTATIONS BY YEAR AND INITIAL ASD GROUP (ROTBYA), BY
C      INITIAL ASD GROUP (TOTASD), BY INITIAL DUTY TYPE (GTDUT),
C      AND BY DUTY TYPE AND INTIAL ASD GROUP (ASDPCT)
C
       DO 45 ASDYG=0,36
          DO 45 DUTY=1,4
             DO 43 TIME=1,15
                ROTBYA(TIME,ASDYG)=ROTBYA(TIME,ASDYG)
     +            +TOTROT(TIME,DUTY,ASDYG)
                TOTASD(ASDYG)=TOTASD(ASDYG)
     +            +TOTROT(TIME,DUTY,ASDYG)
                GTDUT(DUTY)=GTDUT(DUTY)+TOTROT(TIME,DUTY,ASDYG)
                ASDSUM(DUTY,ASDYG)=ASDSUM(DUTY,ASDYG)
     +            +TOTROT(TIME,DUTY,ASDYG)
 43          CONTINUE
 45    CONTINUE
C
C      CALCULATE 'ASDPCT' (MAKEUP OF INITIAL DUTY TYPES,BY ASD
C      GROUPS)
C
       DO 48 ASDYG=0,36
          DO 48 DUTY=1,4
             IF(GTDUT(DUTY).NE.0)ASDPCT(DUTY,ASDYG)=
     +       ASDSUM(DUTY,ASDYG)/GTDUT(DUTY)*100
 48    CONTINUE
```

```
C
C     WRITE TO INPUT.DAT THE INFORMATION IN ASDPCT
C
      WRITE(7,802)
      DO 50 ASDYG=2,36
         ASD=ASDYG/2
         WRITE(7,803)ASD,ASDPCT(1,ASDYG),ASDPCT(2,ASDYG),
     +    ASDPCT(3,ASDYG),ASDPCT(4,ASDYG)
 50   CONTINUE
C
C     CALCULATE 'DUTPCT' (DISTRIBUTION OF EACH INITIAL ASD
C     GROUP, BY DUTY)
C
      DO 55 DUTY=1,4
         DO 55 ASDYG=0,36
            IF(TOTASD(ASDYG).NE.0)DUTPCT(DUTY,ASDYG)=
     +      ASDSUM(DUTY,ASDYG)/TOTASD(ASDYG)*100
 55   CONTINUE
C
      WRITE(7,804)
C
C     WRITE TO INPUT.DAT THE INFORMATION IN DUTPCT
C
      DO 58 I=2,36
         ASD=I/2
         WRITE(7.803)ASD,DUTPCT(1,I),DUTPCT(2,I),DUTPCT(3,I),
     +   DUTPCT(4,I)
 58   CONTINUE
C
C     CALCULATE 'FLYPCT' WHICH IS THE MAKEUP OF EACH INITIAL ASD

C     YEAR GROUP BROKEN OUT BY FLYING CREDIT
C
      DO 60 ASDYG=0,36
         DO 60 FLYCRE=0,22
            IF(TOTASD(ASDYG).NE.0)FLYPCT(ASDYG,FLYCRE)=
     +      FLYTOT(ASDYG,FLYCRE)/TOTASD(ASDYG)*100
 60   CONTINUE
C
C     WRITE FLYPCT STATISTICS
C
      WRITE(7,805)
      DO 65 ASDYG=12,36
         ASD=ASDYG/2
         WRITE(7,806)ASD,FLYPCT(ASDYG,11),FLYPCT(ASDYG,12),
     +   FLYPCT(ASDYG,13),FLYPCT(ASDYG,14),FLYPCT(ASDYG,15),
     +   FLYPCT(ASDYG,16),FLYPCT(ASDYG,17),FLYPCT(ASDYG,18),
     +   FLYPCT(ASDYG,19),FLYPCT(ASDYG,20),FLYPCT(ASDYG,21),
     +   FLYPCT(ASDYG,22)
 65   CONTINUE
```

```
C
C     CALCULATE TIME-ON-STATION STATISTICS
C
      DO 70 DUTY=1,4
         DO 70 I=1,9
            SUMDAS(DUTY)=SUMDAS(DUTY)+TOTDAS(I,DUTY)
            SUMTOS(I)=SUMTOS(I)+TOTDAS(I,DUTY)
 70   CONTINUE
C
C     WRITE DATE-ARRIVED-STATION INFORMATION TO 'INPUT.DAT'
C
      WRITE(7,900)FY(1)-4,FY(1)-4,FY(1)-3,FY(1)-2,FY(1)-1
      DO 75 J=1,4
         WRITE(7,901)J,TOTDAS(9,J),TOTDAS(8,J),TOTDAS(7,J),
     +   TOTDAS(6,J),TOTDAS(5,J),TOTDAS(4,J),TOTDAS(3,J),
     +   TOTDAS(2,J),TOTDAS(1,J),SUMDAS(J)
 75   CONTINUE
      WRITE(7,902)SUMTOS(9),SUMTOS(8),SUMTOS(7),SUMTOS(6),
     +SUMTOS(5),SUMTOS(4),SUMTOS(3),SUMTOS(2),SUMTOS(1)
C
C     CALCULATE THE NUMBER OF INDIVIDUALS THAT ARE ALWAYS IN THE

C     MWS BUT THEIR FIRST ROTATION 'INTO THE NETWORK' IS
C     SCHEDULED DOWNSTREAM.  THESE INDIVIDUALS ARE FILLING
C     MANNING POSITIONS BUT THE NETWORK DOESN'T KNOW ABOUT THEM
C     AT THIS POINT.  VALUES OF ADJUST(TIME) ARE USED TO ADJUST
C     THE RHS OF SIDE CONSTRAINT MANNING REQUIRENTS.
C
      DO 80 TIME=1,9
         DO 80 DUTY=1,4
            DO 80 I=TIME+1,9
               DO 80 ASDYG=0,36
            ADJUST(TIME,DUTY)=ADJUST(TIME,DUTY)+
     +               TOTROT(I,DUTY,ASDYG)
 80   CONTINUE
      DO 81 I=10,MODTIME
         ADJUST(I,1)=0.0
         ADJUST(I,2)=0.0
         ADJUST(I,3)=0.0
         ADJUST(I,4)=0.0
 81   CONTINUE
C
C     OUTPUT MORE INFORMATION TO INPUT.DAT
C
      WRITE(7,808)
      WRITE(7,807)FY(1),FY(2),FY(3),FY(4),FY(5)
C
C     I = FROM DUTY, J = INITIAL ASD GROUP
C
      DO 85 I=1,4
```

```
          WRITE(7,809)
          DO 85 J=2,36
             ASD=REAL(J/2)
             WRITE(7,810)I,ASD,TOTROT(1,I,J),TOTROT(2,I,J),
     +       TOTROT(3,I,J),TOTROT(4,I,J),TOTROT(5,I,J),
     +       TOTROT(6,I,J),TOTROT(7,I,J),TOTROT(8,I,J),
     +       TOTROT(9,I,J),totrot(10,i,j)
 85    CONTINUE
C
C      ROTATIONS THAT HAVE ALREADY FAILED TO MEET THEIR GATES
C
       WRITE(7,811)FY(1),FY(2),FY(3),FY(4),FY(5)
       WRITE(7,812)'1ST GATE',FAILG1(1)+FAILG1(2),FAILG1(3)+
     +FAILG1(4),FAILG1(5)+FAILG1(6),FAILG1(7)+FAILG1(8),
     +FAILG1(9)
       WRITE(7,812)'2ND GATE',FAILG2(1)+FAILG2(2),FAILG2(3)+
     +FAILG2(4),FAILG2(5)+FAILG2(6),FAILG2(7)+FAILG2(8),
     +FAILG2(9)
       WRITE(7,812)'3RD GATE',FAILG3(1)+FAILG3(2),FAILG3(3)+
     +FAILG3(4),FAILG3(5)+FAILG3(6),FAILG3(7)+FAILG3(8),
     +FAILG3(9)
 800   FORMAT(//'  INPUT PARAMETERS'/)
 801   FORMAT(' DUTY TYPE:',10X,'FLY',4X,'SUP',4X,'AFIT',3X,
     +'PME'/' ','duty duration: ',6x,I3,2(3X,I3),3X,I3)
 802   FORMAT('1'//,'  DUTY COMPOSITION STATISTICS'/' NOTE:',
     +'  these figures represent the situation after the ',
     +'model'/' has forced certain duty,ASD, and gate credit',
     +'combinations'//' (columns sum to 100 percent)'//' ',
     +14X,'type that belong to each asd group'//' ',
     +'asd group         fly        sup        afit       pme'/
     +' ','---------         ---        ---        ----       ---')
 803   FORMAT(' ',3X,F4.1,8X,4(F4.0,6X))
 804   FORMAT(///'  (rows sum to 100 percent)'//
     +' ',14X,'percent of total personnel in each'/
     +' ',14X,'asd group that are in each duty type'//
     +' ','asd group',7X,'fly',7X,'sup',7X,'afit',6X,'pme'/
     +' ',8('-'),8X,3('-'),7X,3('-'),7X,4('-'),6X,3('-'))
 805   FORMAT(///' ','ASD GROUP COMPOSITION STATISTICS'/' NOTE:
     +','These numbers are after the model'/' has forced ',
     +'certain combinations'/' (rows sum ',
     +'to 100 percent)',//' ',12X,'% of each asd group by gate ',
     +'credit accumulated'//
     +' asd group       6 yrs     7 yrs      8 yrs        ',
     +'9 yrs    10 yrs   11 yrs'/
     +' ---------       --------  --------   -------- ',
     +'-------- -------  -------- ')
 806   FORMAT(' ',4X,F4.1,6X,6(F3.0,2X,F3.0,2X))
 807   FORMAT(/' ','YEAR',14X,I4,9X,4(I4,11X)/
     +18X,'-------',7X,'-------',7X,'-------',5X,'-------',
     +7X,'-------')
```

```
 808  FORMAT('1','TOTAL ROTATIONS' ' ','grouped by "from" ',
     +'duty and "initial" asd group'/' each year has two half',
     +' periods')
 809  FORMAT(' ',' ')
 810  FORMAT(' ','DUTY',I2,'; ASD ',F4.1,1X,F3.0,1X,F3.0,6X,
     +4(F3.0,2X,F3.0,6X))
 811  FORMAT(//' ','ROTATIONS THAT HAVE MISSED THEIR GATES',
     +//' YEAR:',16X,5(I4,7X)/'
+',17X,'-------',4X,4('-------',4X)/)
 812  FORMAT(' ',A8,12X,5(I3,7X))
 900  FORMAT(//' ARRIVED-STATION STATISTICS'/' Number that
     +arrived',' at initial duty station'/' during indicated
     +time periods.'/' 1st column = fy 1st half, 2nd column
     += fy 2nd half'//
     +'  duty  before'/
     +'  type  ',1x,'FY',I2,4X,4(1X,'FY',I2,5X),'total'/
     +' ------','------',1x,4('---------',1x),'-------')
 901  FORMAT(' ',4X,I1,3X,F4.0,2X,4(F4.0,1X,F4.0,1X),1X,F5.0)
 902  FORMAT(' ','TOTAL',2X,I4,3X,4(I3,2X,I3,2X))
      close(unit=7)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     SECTION ROWS
C     THIS SECTION OF CODE WILL BUILD THE ROWS SECTION OF A
C     STANDARD MPS FILE.
C        THE ROWS SECTION NAMES EACH CONSTRAINT.  THERE ARE TWO
C        SEPERATE TYPES OF CONSTRAINTS IN THIS NETWORK:  (1)
C        CONSTRAINTS CORRESPONDING TO EACH NODE IN THE NETWORK,
C        AND (2) CONSTRAINTS REPRESENTING SIDE RESTRICTIONS (SUCH
C        AS MANPOWER REQUIREMENTS AND EXPERIENCE LEVEL
C        REQUIREMENTS.
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C
      OPEN (UNIT=10,FILE='ROWS.DAT',STATUS='NEW')
C
C     FIRST, WRITE A RECORD WHICH NAMES THE SECTION.  IN THIS
C     CASE THE NAME OF THE SECTION IS 'ROWS'
C
      WRITE(10,500)
C
C     NEXT, ADD A ROW TYPE N (FREE ROW)
C     THIS ROW WILL SPECIFY THE OBJECTIVE FUNCTION
C
      WRITE(10,505)
C
C     LOOP TO ASSIGN SUCCESSIVE NODE NUMBERS TO ALL MODELED
C     COMBINATIONS OF TIME, DUTY, ASD YEAR GROUP, AND FLYING
C     CREDIT.
```

```
C
      NODNUM=1
C
C     HALF YEAR INCREMENTS FOR 5 YEARS
C
      DO 90 TIME=1,MODTIME
C
C     FOUR SEPERATE DUTY TYPES
C
        DO 90 DUTY=1,4
C
C     56 ASD YEAR GROUPS (HALF YEAR INCREMENTS FOR 18 YEARS)
C
           DO 90 ASDYG=0,NUMASD
C
C     IF ASDYG IS LESS THAN 6 YEARS, THEN THE MINIMUM FLYING
C     CREDIT ACCUMULATED IS THE ASDYG.
C     IF ASDYG IS GREATER THAT 6 YEARS, THEN THE MINIMUM FLYING
C     CREDIT IS 6 YEARS.
C     IF ASDYG IS GREATER THAN 11 YEARS TEN RESTRICT MAXIMUM
C     FLYING CREDIT TO 11 YEARS.
C
              IF(ASDYG .LT. 12) THEN
                 MINFLY=ASDYG
              ELSE
                 MINFLY=12
              ENDIF
              IF(ASDYG.GT.22) THEN
                 MAXFLY=22
              ELSE
                 MAXFLY=ASDYG
              ENDIF
C
              DO 90 FLYCRE=MINFLY,MAXFLY
                 FLAG1=0
C
C     ASD YEAR GROUPS LT 6 YEARS CAN ONLY BE IN FLYING JOBS
C
                 IF(DUTY.NE.1.AND.ASDYG.LT.12) FLAG1=1
C
C     ASD YEAR GROUPS GT 13 YEARS CAN NOT BE IN AFIT
C
                 IF(DUTY.EQ.3.AND.ASDYG.GT.26) FLAG1=1
C
C     PME IS ONLY AVAILABLE TO ASD YEAR GROUPS
C     13-15 (ISS), AND 18+ (SSS).
C
                 IF(DUTY.EQ.4) THEN
                    IF(ASDYG.LT.26)FLAG1=1
                    IF(ASDYG.GT.30.AND.ASDYG.LT.36)FLAG1=1
```

```
                  ENDIF
C
                  IF(FLAG1.NE.1) THEN
                    NODNUM=NODNUM+1
                    NODE(TIME,DUTY,ASDYG,FLYCRE,0)=NODNUM
                    WRITE(10,510)NODNUM
                  ENDIF
 90     CONTINUE
C
C       NEED SOME ADDITIONAL CONSTRAINTS WHICH PREVENT THE AFIT
C       POSITIVE DEVIATION VARIABLES FROM EXCEEDING 5.
C
        DO 96 TIME=1,MODTIME
           NODNUM=NODNUM+1
           AFIT(TIME)=NODNUM
           WRITE(10,506)NODNUM
 96     CONTINUE
C
        MAXNOD=NODNUM+1
C
C       INITIALIZE THE ARRAY MANCON WHICH DEFINES THE MANPOWER
C       CONSTRAINTS FOR DUTY TYPES 'OPS', 'AFIT', 'PME', AND 'SUP'.
C
        DO 95 TIME=1,MODTIME
          DO 95 DUTY=1,4
             MANCON(TIME,DUTY)=MAXNOD
             WRITE(10,510)MAXNOD
             MAXNOD=MAXNOD+1
 95     CONTINUE
C
C
        MAXNOD=MAXNOD-1
C
C       NEED  ADDITIONAL NODES TO REPRESENT THE END-OF-NETWORK
C       NODES.  THESE NODES EACH REPRESENT ASDYG AND DUTY
C       COMBINATION.  THE DUTY COMBINATIONS ARE ONLY TWO,
C       OPERATIONAL FLYING ASSIGNMENTS AND OTHER.
C
        NEXT=MAXNOD+1
        DO 102 ASDYG=1,NUMASD/2
           DO 102 DUTY=1,2
              WRITE(10,510)NEXT
              NEXT=NEXT+1
 102    CONTINUE
        CLOSE(UNIT=10)
C
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C         SECTION COLUMNS
```

```
C
C        BUILD COLUMNS SECTION OF MPS FILE (FOR FLOWS ON ARCS)
C        FOR EACH VARIABLE (EACH FLOW ON ARC) THE COLUMN SECTION
C        LISTS THE NONZERO ENTRIES IN THE CORRESPONDING COLUMN OF
C        CONSTRAINT MATRIX.  NONZERO ENTRIES WILL BE 1.0 UNLESS
C        THE ARC FLOWING INTO THE NODE HAS A GAIN ASSOCIATED WITH
C        IT. (GAINS REPRESENT ATTRITION RATES).
C        EACH FLOW, X, SHOULD APPEAR IN ONLY TWO NODAL CONSTRAINT
C        FORMULAS; THE NODE IT FLOWS INTO AND THE NODE IT
C        ORIGINATES FROM. ADDITIONALLY, SOME FLOWS WILL CONTRIBUTE
C        TO SIDE CONSTRAINTS
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      OPEN(UNIT=7,FILE='COLUMN.DAT',STATUS='NEW')
      WRITE(7,515)
C
C    LOOP TO CALCULATE COMBINATIONS OF BEGINNING AND ENDING NODES
C
      FLOWNUM=0
      DO 150 ENDDUT=1,4
C
C     TEN TIME PERIODS (HALF YEAR INCREMENTS)
C
         DO 150 TIME=1,MODTIME
C
C     FOUR DUTY TYPES
C
            DO 150 DUTY=1,4
C
C     AFIT CAN ONLY ROTATE TO SUP
C
               IF(DUTY.EQ.3.AND.ENDDUT.NE.2) GOTO 145
C
C     PME CANNOT ROTATE TO PME
C
               IF(DUTY.EQ.4.AND.ENDDUT.EQ.4) GOTO 145
                  DO 150 ASDYG=0,NUMASD
C
C     DO NOT ALLOW ASD YEAR GROUPS LESS THAN 6 TO ROTATE INTO
C     NONFLYING JOBS.  THIS IS ALREADY ACCOMPLISHED FOR YEARS 1-5
C     BY STRUCTURAL CONSTRAINTS; THE CORRESPONDING NODES DO NOT
C     EXIST. HOWEVER, FOR THE END-OF-NETWORK NODES THIS MUST BE
C     DIRECTLY SPECIFIED.
C
                     IF(ENDDUT.NE.1.AND.ASDYG.LT.12) GOTO 145
                     IF(ASDYG.LT.12) THEN
                       MINFLY=ASDYG
                     ELSE
                       MINFLY=12
```

```
                    ENDIF
                    IF(ASDYG.GT.22) THEN
                      MAXFLY=22
                    ELSE
                      MAXFLY=ASDYG
                    ENDIF
C
                    DO 144 FLYCRE=MINFLY,MAXFLY
C
C     THE DUTY TYPES 1 AND 2 (OPS OR SUP) HAVE THREE DIFFERENT
C     DUTY DURATIONS POSSIBLE LEAVING THE NODE.
C     THESE DUTY DURATIONS ARE FOUND IN THE ARRAYS OPSLEN AND
C     SUPLEN.  THE DUTY TYPES 3 AND 4 (AFIT OR PME) ONLY HAVE ONE
C     DEFINED DUTY DURATION
C     THE VARIABLE CYCLE IS USED TO DETERMINE HOW MANY DIFFERENT
C     DUTY DURATIONS ARE ASSOCIATED WITH THE DUTY TYPE.
C
                      CYCLE=1
                      IF(ENDDUT.EQ.3.OR.ENDDUT.EQ.4)COUNT2=1
                      IF(ENDDUT.EQ.1.OR.ENDDUT.EQ.2)
     +                COUNT2=CYCLE
                      IF(ASDYG.GE.36)COUNT2=1
                      DO 142 COUNT1=1,COUNT2
                        IF(ENDDUT.EQ.1)DUR=OPSLEN(COUNT1)
                        IF(ENDDUT.EQ.2)DUR=SUPLEN(COUNT1)
                        IF(ENDDUT.EQ.3.OR.ENDDUT.EQ.4)
     +                  DUR=DUTDUR(ENDDUT)
                        IF(ASDYG.GE.36)DUR=3
C
C     ANY NODE ASSIGNED A NONZERO NODE NUMBER (IN THE ROWS
C     SECTION) IS EXAMINED AS A POSSIBLE BEGINNING NODE.
C     FOR THOSE WHICH LEAD TO A POSSIBLE (NONZERO) END NODE VIA
C     ASSIGNMENT ARCS, AN ENTRY IS MADE IN THE ARRAY FLOW.
C
                        BEGNOD=NODE(TIME,DUTY,ASDYG,FLYCRE,0)
                        IF(BEGNOD.NE.0) THEN
C
C     CALCULATE ASD YEAR GROUP AT END OF ASSIGNMENT
C
                          NEWASD=ASDYG+DUR
                          IF(NEWASD.GT.NUMASD)NEWASD=NUMASD
C
C     CALCULATE FLYING CREDIT AT END OF ASSIGNMENT
C
                          IF(ENDDUT.EQ.1) THEN
                            NEWFLY=FLYCRE+DUR
                            IF(NEWFLY.GT.22)NEWFLY=22
                          ELSE
                            NEWFLY=FLYCRE
                          ENDIF
```

```
C
C     ANY ASSIGNMENTS THAT WOULD TERMINATE BEYOND THE TIME
C     HORIZON OF THE MODEL ARE ROUTED TO NODE MAXNOD+END DUTY
C
C     DETERMINE IF ANY OF THE FLOWS ARE INFEASIBLE.
C     IF THEY ARE, THEN DON'T PROCESS THE FLOW.
C
                                         ENDTIM=TIME+DUR
                                         IF(ENDTIM.GT.MODTIME) THEN
C
C     IF DUTY IS AFIT (ENDDUT=3) AND ASD IS GT 13 YEARS, THE
C     FLOW IS INFEASIBLE.
C
                                           IF(ENDDUT.EQ.3.AND.NEWASD.GT.26)
     +                                     GOTO 142
C
C     IF DUTY IS PME THEN THE FLOW IS INFEASIBLE IF ASD LT 13 YRS
C
                                           IF(ENDDUT.EQ.4) THEN
                                             IF(NEWASD.LT.26) GOTO 142
C
C     INFEASIBLE IF ASD BETWEEN 15 AND 18 YRS
C
                                             IF(NEWASD.GT.30.AND.NEWASD.LT.36)
     +                                       GOTO 142
                                           ENDIF
C
C     IF ENDING NODE IS PAST THE MODEL'S TIME HORIZON THEN
C     FLOWS FROM THE BEGINNING NODE ARE ROUTED TO "SINK
C     NODES".  THESE SINK NODES ARE GROUPED BY DUTY TYPE/
C     ASD COMBINATION.  FOR 21 ASD YEAR GROUPS (IN HALF YEAR
C     INCREMENTS THIS EQUALS 42 TOTAL).
C
                                           NEWASD=ASDYG+(ENDTIM-MODTIME)
                                           IF(ENDDUT.EQ.1)NEWFLY=
     +                                     FLYCRE+(ENDTIM-MODTIME)
                                           IF(ENDDUT.EQ.1)ENDNOD=MAXNOD+
     +                                     INT(NEWASD+1/2)
                                           IF(ENDDUT.NE.1)ENDNOD=MAXNOD+
     +                                     INT(NEWASD+1/2)
                                         ELSE
                                           ENDNOD=NODE(
     +                                     ENDTIM,ENDDUT,NEWASD,NEWFLY,0)
                                         ENDIF
C
C     IF AN END NODE EXISTS THEN RECORD ALL PERTINENT INFORMATION
C     THE ARRAY FLOW IS USED IN THE OUTPUT SUBROUTINE.
C
                                         IF(ENDNOD.NE.0) THEN
                                            FLOWNUM=FLOWNUM+1
```

```
                     FLOW(FLOWNUM,1)=BEGNOD
                     FLOW(FLOWNUM,2)=ENDNOD
                     FLOW(FLOWNUM,4)=TIME
                     IF(ENDTIM.GT.MODTIME)ENDTIM=MODTIME
                     FLOW(FLOWNUM,5)=ENDTIM
                     FLOW(FLOWNUM,6)=ASDYG
                     FLOW(FLOWNUM,7)=NEWASD
                     FLOW(FLOWNUM,8)=FLYCRE
                     FLOW(FLOWNUM,9)=NEWFLY
                     FLOW(FLOWNUM,11)=DUTY
                     FLOW(FLOWNUM,12)=ENDDUT
                  ELSE
                     GOTO 142
                  ENDIF
C
C     ASSIGN ARC COSTS TO THOSE FLOWS WHICH LEAD DIRECTLY TO NON-
C     ACHIEVEMENT OF FLYING GATES.
C     EARLIER IN THE PROGRAM ARBITRARY COSTS WERE ASSIGNED TO
C     NON-ACHIEVEMENT OF FLYING GATES 1,2, AND 3.  THESE ARE
C     FOUND IN THE ARRAY COST(1:3,1:3).
C        THE FIRST INDEX IS THE GATE NUMBER (1,2,3)
C        THE SECOND INDEX HOLDS THREE SEPERATE VALUES WHICH
C        CORRESPOND TO THAT GATE.
C           VALUE 1 IS THE COST
C           VALUE 2 IS THE ASD YEAR ASSOCIATED WITH THE GATE
C           VALUE 3 IS THE FLYING CREDIT
C
                  FLAG=0
                  ARCOST=0
                  FLOW(FLOWNUM,13)=0
                  IF(NEWASD.GE.24.AND.NEWFLY.LT.12)THEN
                     FLAG=1
                     ARCOST=COST(1,1)
                     FLOW(FLOWNUM,13)=1
                     GOTO 135
                  ENDIF
                  IF(NEWASD.GE.36.AND.NEWFLY.LT.18)THEN
                     FLAG=1
                     ARCOST=COST(2,1)
                     FLOW(FLOWNUM,13)=2
                     GOTO 135
                  ENDIF
                  IF(NEWASD.GE.36.AND.NEWFLY.LT.22)THEN
                     FLAG=1
                     ARCOST=COST(3,1)
                     FLOW(FLOWNUM,13)=3
                  ENDIF
 135              CONTINUE
C
C     THERE ARE CERTAIN ASSIGNMENTS WHICH IF MADE, COULD
```

```
C      ULTIMATELY RESULT IN NON-ACHIEVEMENT OF A GATE.  FOR
C      EXAMPLE, AN INDIVIDUAL WITH 13 YEARS ASD AND 6 YEARS FLYCRE
C      COULD CONCEIVABLY ASSIGNED TO ISS.  HIS/HER ASD WOULD RISE
C      TO 14 AND FLYCRE REMAINS UNCHANGED.  AT THIS POINT, THE
C      INDIVIDUAL COULD BE ASSIGNED TO STAFF DUTY FOR 3.5 YEARS
C      AND ASD=17.5 AND FLYCRE=6.  AT THIS POINT,
C      THE INDIVIDUAL WILL NOT HAVE 9(OR 11) YEARS FLYCRE AT THE
C      18 YEAR POINT.  THE NEXT SECTION WILL DETERMINE IF AN
C      ASSIGNMENT MADE NOW WILL CAUSE NON-ACHIEVEMENT OF A GATE AT
C      A LATER POINT.
C
                          IF(FLAG.EQ.0)THEN
                             FLYCK=NEWFLY+DUTDUR(1)
                             ASDCK=NEWASD+DUTDUR(1)
                             IF(ASDCK.GT.36)THEN
                                IF(FLYCK.LT.18)THEN
                                   FLAG=1
                                   ARCOST=2
                                   GOTO 139
                                ENDIF
                                IF(FLYCK.LT.22)THEN
                                   FLAG=1
                                   ARCOST=1
                                ENDIF
                             ENDIF
                          ENDIF
 139                      CONTINUE
                          RCOST=ARCOST
C
C
C      DETERMINE WHAT MANNING CONSTRAINT THIS FLOW CONTRIBUTES TO
C      IT NOT ONLY CONTRIBUTES TO THE ENDTIM MANNING LEVEL
C      CONSTRAINT FOR THIS DUTY TYPE BUT FOR ALL OTHERS BETWEEN
C      COUNT HOLDS THE NUMBER OF MANNING CONSTRAINTS
C      THE VARIABLE CONTRIBUTES TO.
C
                          COUNT=1
                          DO 140 K=TIME+1,ENDTIM
                             IF(K.GT.MODTIME) GOTO 141
                             MANNING(COUNT)=MANCON(K,DUTY)
                             COUNT=COUNT+1
 140                      CONTINUE
 141                      CONTINUE
C
C      RETENTION IS MODELED AS GAINS ON THE ARCS.
C      DETERMINE WHAT RETENTION VALUE TO USE.
C      IF ENDDUT IS 3 OR 4 (AFIT OR PME), DO NOT ALLOW ANY
C      ATTRITION TO OCCUR (LET RETENTION EQUAL 1.00)
C
                          IF(ENDDUT.EQ.3.OR.ENDDUT.EQ.4)
```

```
     +                           ATRNUM(FLOWNUM)=1.0
C
C      IF ENDDUT IS 1 OR 2 (OPS OR SUP), ATTRITION MUST OCCUR
C      EVERY YEAR FOR THE LENGTH OF THE ASSIGNMENT
C
                                 IF(ENDDUT.EQ.1.OR.ENDDUT.EQ.2)THEN
                                    TEMP=INT(DUTDUR(ENDDUT)/2)
                                    ATRNUM(FLOWNUM)=ATR(TIME,ASDYG)**
     +                              TEMP
                                 ENDIF
C
C      WRITE TO OUTPUT FILE THE MPS FORMAT FOR THIS VARIABLE
C
C
C      IF ENDNOD > MAXNOD THEN THIS ARC'S ENDING NODE IS A
C      SINK NODE.  IN THIS CASE, THE FLOW CONTRIBUTES TWICE
C      TO THE NODAL CONSERVATION OF FLOW CONSTRAINT.
C        FOR EXAMPLE:
C        IF X5 AND X6 ARE FLOWS INTO SINK NODE (ASDYG8,OPS)
C        AND X7 AND X8 ARE FLOWS INTO SINK NODE (ASDYG8,OTHER)
C        AND THE DESIRED PERCENTAGE FOR OPS IS 60% AND OTHER
C        IS 40%, THEN THE NODAL FLOW CONSTRAINT FOR (ASDYG8,OPS):
C          -X5 -X6 +.6X5 +.6X6 +.6X7 +.6X8 + Ni - Pi = 0
C
C        AND THE NODAL FLOW CONSTRAINT FOR (ASDYG8,OTHER) :
C          -X7 -X8 +.4X5 +.4X6 +.4X7 +.4X8 +Ni - Pi = 0
C
C        WHERE Ni AND Pi ARE MINIMIZED IN THE OBJECTIVE FUNCTION
C
C
                                    IF(ENDNOD.LE.MAXNOD)WRITE
     +                              (7,516)FLOWNUM,BEGNOD,ENDNOD,
     +                              ATRNUM(FLOWNUM)
                                    IF(ENDNOD.GT.MAXNOD)THEN
                                       IF(ENDDUT.EQ.1)THEN
                                         TEMP=INT((NEWASD+1)/2)
                                         WRITE(5,517)FLOWNUM,BEGNOD,
     +                                   1.0,ENDNOD,-ATRNUM(FLOWNUM)
     +                                   +STRUCT(TEMP,1)
                                         WRITE(7,517)
     +                                   FLOWNUM,ENDNOD+1,
     +                                   STRUCT(TEMP,2)
                                       ENDIF
                                       IF(ENDDUT.NE.1)THEN
                                         TEMP=INT((NEWASD+1)/2)
                                         WRITE(7,513)FLOWNUM,BEGNOD,
     +                                   1.0,ENDNOD,-ATRNUM(FLOWNUM)
     +                                   +STRUCT(TEMP,2)
                                         WRITE(7,517)FLOWNUM,
     +                                   ENDNOD-1,STRUCT(TEMP,1)
```

```
                                 ENDIF
                              ENDIF
C
C     WRITE OUT ALL THE MANNING LEVEL CONSTRAINTS THAT THIS
C     VARIABLE CONTRIBUTES TO.  AGAIN, IF ENDDUT EQUALS 3 OR 4,
C     (AFIT OR PME) THEN ATRNUM(FLOWNUM)=1.0
C
C
                           FLAG3=0
                           DO 143 K=1,COUNT-1
                              IF (FLAG3.EQ.0) THEN
                                 FLAG3=1
C
C     FLAG3 IS USED TO DETERMINE WHEN THE NEXT LINE OF OUTPUT
C     NEEDS TO BE SENT TO THE OUTPUT FILE.  IF FLAG3 IS 1, THEN
C     SEND THE NEXT LINE.
C     TEMPMAN HOLDS THE NUMBER OF THE NEXT MANNING CONSTRAINT
C     THAT THIS VARIABLE CONTRIBUTES TO.
C     IF ENDDUT IS 3 OR 4 (AFIT OR PME) THEN NO ATTRITION OCCURS

C
                                 TEMPMAN=MANNING(K)
                                 IF(ENDDUT.EQ.3.OR.ENDDUT.EQ.4)
     +                           TEMPATR=1.0
C
C     IF ENDDUT IS 1 OR 2, THEN THE ATTRITION VALUE VARIES WITH
C     HOW MANY YEARS HAVE BEEN SPENT IN THE ASSIGNMENT
C
                                 IF(ENDDUT.EQ.1
     +                           .OR.ENDDUT.EQ.2)THEN
                                    IF(K.LE.3)
     +                              ATRTEMP=ATR(TIME,ASDYG)
                                    IF(K.GT.3.AND.K.LT.5)
     +                              TEMPATR=ATR(TIME,ASDYG)**2
                                    IF(K.GT.5.AND.K.LT.7)
     +                              TEMPATR=ATR(TIME,ASDYG)**3
                                    IF(K.GT.7.AND.K.LT.9)
     +                              TEMPATR=ATR(TIME,ASDYG)**4
                                 ENDIF
                                 GOTO 143
                              ELSE
C
C     FLAG3 IS EQUAL TO 1 SO MUST WRITE OUT A LINE TO THE OUTPUT
C     FILE.
C
                                 FLAG3=0
                                 IF(ENDDUT.EQ.3.OR.ENDDUT.EQ.4)
     +                           ATRNUM(FLOWNUM)=1.0
C
C     IF ENDDUT IS 1 OR 2 (OPS OR SUP), ATTRITION MUST OCCUR
```

```
C     EVERY YEAR FOR THE LENGTH OF THE ASSIGNMENT
C
                                    IF(ENDDUT.EQ.1.OR.ENDDUT.EQ.2)
     +                              THEN
                                       IF(K.LE.3)ATRNUM(FLOWNUM)=
     +                                 ATR(TIME,ASDYG)
                                       IF(K.GT.3.AND.K.LE.5)ATRNUM
     +                                 (FLOWNUM)=ATR(TIME,ASDYG)**2
                                       IF(K.GT.5.AND.K.LE.7)ATRNUM
     +                                 (FLOWNUM)=ATR(TIME,ASDYG)**3
                                       IF(K.GT.7.AND.K.LE.9)ATRNUM
     +                                 (FLOWNUM)=ATR(TIME,ASDYG)**4
                                    ENDIF
                                    WRITE(7,513)FLOWNUM,TEMPMAN,
     +                              ATRNUM(FLOWNUM),MANNING(K),
     +                              ATRNUM(FLOWNUM)
                                 ENDIF
 143                          CONTINUE
C
C     IF FLAG3 IS EQUAL TO 1, THEN THERE IS ONE LINE OF OUTPUT
C     THAT STILL NEEDS TO BE WRITTEN OUT TO THE OUTPUT FILE
C
                                 IF(FLAG3.EQ.1)THEN
                                    IF(ENDDUT.EQ.3.OR.ENDDUT.EQ.4)
     +                              ATRNUM(FLOWNUM)=1.0
                                    IF(ENDDUT.EQ.1.OR.ENDDUT.EQ.2)
     +                              THEN
                                       IF(K.LE.3)ATRNUM(FLOWNUM)=
     +                                 ATR(TIME,ASDYG)
                                       IF(K.GT.3.AND.K.LE.5)
     +                                 ATRNUM(FLOWNUM)
     +                                 =ATR(TIME,ASDYG)**2
                                       IF(K.GT.5.AND.K.LE.7)
     +                                 ATRNUM(FLOWNUM)
     +                                 =ATR(TIME,ASDYG)**3
                                       IF(K.GT.7.AND.K.LE.9)
     +                                 ATRNUM(FLOWNUM)
     +                                 =ATR(TIME,ASDYG)**4
                                    ENDIF
                                    WRITE(7,517)FLOWNUM,TEMPMAN,
     +                              ATRNUM(FLOWNUM)
                                 ENDIF
C
C
C     IF THE ENDING NODE IS PAST THE END OF THE NETWORK THEN
C      THIS VARIABLE CAN NOT CONTRIBUTE TO THE OBJECTIVE FUNCTION
C
                                IF(ENDNOD.GT.MAXNOD)GOTO 142
C
C     IF FLAG = 1 THEN THIS VARIABLE CONTRIBUTES TO THE OBJECTIVE
```

```
C     FUNCTION.  RCOST HOLDS THE COST OF THIS FLOW
C
                              IF(FLAG.EQ.1)WRITE(7,514)
     +                        FLOWNUM,RCOST
                          ENDIF
 142                    CONTINUE
 144                  CONTINUE
 145     CONTINUE
 150  CONTINUE
      MAXFLOW=FLOWNUM
C
C     THE NEXT SECTION OF CODE WILL DETERMINE THE DEVIATION
C     VARIABLES AND THEIR APPROPRIATE CORRESPONDING CONSTRAINTS
C
C     DEVIATION VARIABLES ARE FOUND IN CONSTRAINTS FOR MANNING
C     CONSTRAINTS.  THE GENERAL FORM FOR THESE CONSTRAINTS IS:
C             Fi(x) + Ni - Pi = Bi
C     WHERE   Fi(x) is the ith constraint
C             Ni is the negative deviation from Bi
C             Pi is the positive deviation from Bi
C
C     EACH DEVIATION VARIABLE IS IN ONLY ONE CONSTRAINT
C     START THE NUMBERING FOR THESE VARIABLES AT MAXFLOW+1
C
      DEVVAR=MAXFLOW+1
C
C     DETERMINE THE DEVIATION VARIABLES FOR THE MANNING
C     CONSTRAINTS.
C
      DO 160 TIME=1,MODTIME
        DO 160 DUTY=1,4
           IF (DUTY.EQ.1)WEIGH=WEIGHT(1)
           IF(DUTY.EQ.2)WEIGH=WEIGHT(2)
           IF(DUTY.EQ.3)WEIGH=WEIGHT(3)
           IF(DUTY.EQ.4)WEIGH=WEIGHT(4)
           WRITE(7,524)DEVVAR,MANCON(TIME,DUTY),WEIGH
C
C     MAKE A CORRESPONDING ENTRY IN THE ARRAY FLOW.
C     FLOW(DEVVAR,4) AND FLOW(DEVVAR,5) = 0
C     THIS ENTRY WILL BE USED IN THE OUTPUT DRIVER.
C
           FLOW(DEVVAR,4)=0
           FLOW(DEVVAR,5)=0
           DEVVAR=DEVVAR+1
           WRITE(7,525)DEVVAR,MANCON(TIME,DUTY),WEIGH
C
C     IF DUTY IS AFIT (3), THEN NEED A VARIABLE WHICH WILL
C     CONTRIBUTE TO THE AFIT CONSTRAINT
           IF(DUTY.EQ.3)WRITE(7,512)DEVVAR,AFIT(TIME)
           FLOW(DEVVAR,4)=0
```

```
            FLOW(DEVVAR,5)=0
            DEVVAR=DEVVAR+1
 160   CONTINUE
C
C      NEXT, DETERMINE THE DEVIATION VARIABLES FOR THE ENDING
C      STRUCTURE NODAL CONSTRAINTS.
C      THERE ARE (ASD FULL YEAR GROUPS * 2) ENDING NODES ("SINK C
C      NODES")
C
       WEIGH=WEIGHT(5)
       DO 161 I=1,NUMASD
          WRITE(7,524)DEVVAR,MAXNOD+I,WEIGH
          FLOW(DEVVAR,4)=0
          FLOW(DEVVAR,5)=0
          DEVVAR=DEVVAR+1
          WRITE(7,525)DEVVAR,MAXNOD+I,WEIGH
          FLOW(DEVVAR,4)=0
          FLOW(DEVVAR,5)=0
          DEVVAR=DEVVAR+1
 161   CONTINUE
C
       CLOSE(UNIT=7)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C            SECTION RHS
C         THIS SECTION OF CODE WILL BUILD THE RHS SECTION OF
C            THE MPS INPUT FILE
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
       OPEN(UNIT=10,FILE='RHS.DAT',STATUS='NEW')
       WRITE(10,530)
       FLAG2=0
C
       DO 170 TIME=1,MODTIME
          DO 170 DUTY=1,4
             DO 170 ASDYG=0,NUMASD
                IF (ASDYG.LT.12)THEN
                   MINFLY=ASDYG
                ELSE
                   MINFLY=12
                ENDIF
                IF(ASDYG.GT.22)THEN
                   MAXFLY=22
                ELSE
                   MAXFLY=ASDYG
                ENDIF
                DO 170 FLYCRE=MINFLY,MAXFLY
                   EXTFLO=0
                   EXTFLO=NODE(TIME,DUTY,ASDYG,FLYCRE,1)
```

```
                     IF(EXTFLO.NE.0.00)THEN
                        IF(FLAG2.EQ.0)THEN
                           FLAG2=1
                           TEXTFLO=EXTFLO
                           TNODNUM=NODE(TIME,DUTY,ASDYG,FLYCRE,0)
                           GOTO 169
                        ENDIF
                        IF(FLAG2.EQ.1) THEN
                           FLAG2=0
                           NODNUM=NODE(TIME,DUTY,ASDYG,FLYCRE,0)
                          WRITE(10,535)TNODNUM,TEXTFLO,NODNUM,EXTFLO
                        ENDIF
 169                    CONTINUE
                     ENDIF
 170  CONTINUE
      IF(FLAG2.NE.0) WRITE(10,534) TNODNUM,TEXTFLO
C
C     THE RHS FOR THE MANNING CONSTRAINTS
C
      FLAG2=0
      DO 180 TIME=1,MODTIME
         DO 180 DUTY=1,4
            IF(FLAG2.EQ.0)THEN
               FLAG2=1
               TNODNUM=MANCON(TIME,DUTY)
               IF(DUTY.NE.1)TRHS=RQMT(TIME,DUTY)-
     +         ADJUST(TIME,DUTY)
               IF(DUTY.EQ.1)TRHS=RQMT(TIME,DUTY)-
     +         ADJUST(TIME,DUTY)-FAIP(TIME)-UFT(TIME)
            ELSE
               FLAG2=0
               NODNUM=MANCON(TIME,DUTY)
               IF(DUTY.NE.1)RHS=RQMT(TIME,DUTY)-
     +         ADJUST(TIME,DUTY)
               IF(DUTY.EQ.1)RHS=RQMT(TIME,DUTY)-
     +         ADJUST(TIME,DUTY)-FAIP(TIME)-UFT(TIME)
               WRITE(10,535)TNODNUM,TRHS,NODNUM,RHS
            ENDIF
 180  CONTINUE
C
C     NEED RHS FOR THE AFIT POSITIVE DEVIATION CONSTRAINTS
C     THESE CONSTRAINTS RESTRICT THE VALUE OF THE POSITIVE
C     DEVIATION VARIABLES TO 5 OR LESS.
C
      DO 181 TIME=1,MODTIME
         NODNUM=AFIT(TIME)
         RHS=5.0
         WRITE(10,534)NODNUM,RHS
 181  CONTINUE
C
```

```
C     NEED RHS FOR THE (SINK) ENDING NODES
C
      DO 182 I=1,NUMASD
         RHS=0.0
         WRITE(10,534)MAXNOD+I,RHS
 182  CONTINUE
      CLOSE(UNIT=10)
C
 500  FORMAT('ROWS')
 505  FORMAT(' N  N00001')
 506  FORMAT(1X,'L',2X,'N',I5)
 510  FORMAT(1X,'E',2X,'N',I5)
 511  FORMAT(1X,'G',2X,'N',I5)
 512  FORMAT(4X,'X',I5,4X,'N',I5,4x,'1.0')
 513  FORMAT(4X,'X',I5,4X,'N',I5,4X,F8.4,7X,'N',I5,4X,F8.4)
 514  FORMAT(4X,'X',I5,4X,'N00001',4X,F6.3)
 515  FORMAT('COLUMNS')
 516  FORMAT(4X,'X',I5,4X,'N',I5,4X,'1.0',12X,'N',I5,4X,'-',F7.4)
 517  FORMAT(4X,'X',I5,4X,'N',I5,4X,F8.4)
 522  FORMAT(4X,'X',I5,4X,'N',I5,4X,'1.0',12X,'N00001',4X,F7.4)
 523  FORMAT(4X,'X',I5,4X,'N',I5,4X,'-1.0',11X,'N00001',4X,F7.4)
 524  FORMAT(4X,'X',I5,4X,'N',I5,4X,'1.0',12X,'N00001',4X,F7.4)
 525  FORMAT(4X,'X',I5,4X,'N',I5,4X,'-1.0',11X,'N00001',4X,F7.4)
 526  FORMAT(I5,6(2X,I2),3(2X,I1))
 527  FORMAT(I5)
 530  FORMAT('RHS')
 534  FORMAT(4X,'RHS01',5X,'N',I5,4X,F8.2)
 535  FORMAT(4X,'RHS01',5X,'N',I5,4X,F7.2,8X,'N',I5,4X,F7.2)
 536  FORMAT(A4,I4,I4,I3,8(I4))
 537  FORMAT(F6.4)
 538  FORMAT(F7.2)
      RETURN
      END
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C           SUBROUTINE INSERT
C
C           THIS SUBROUTINE IS USED TO CREATE THE NECESSARY
C           FORMAT NEEDED BY MINOS.  MINOS WILL NOT ACCEPT BLANKS
C           IN THE NAME FIELDS SO THIS SUBROUTINE WILL INSERT 0s
C           IN PLACE OF THE BLANKS IN ALL THE NAME FIELDS (BOTH C
         ROWS AND COLUMNS)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      SUBROUTINE INSERT
      COMMON/FIRST/MAXNOD,MAXFLOW,RQMT,FLOW,ATR,ASDSUM,MODTIME
      COMMON/FIRST/FAIP
      CHARACTER*1 VAR
```

```
      CHARACTER*6 NODES,NODES1
      CHARACTER*6 VARNAM,RHSNAM
      CHARACTER*7 NAME
      CHARACTER*11 OBFUN
      CHARACTER*12 COEF1,COEF2
      INTEGER MAXNOD,MAXFLOW
C
C     OPEN THE FILES CONTAINING THE ROW AND COLUMN DATA
C
      OPEN(UNIT=8,FILE='COLUMN.DAT',STATUS='OLD')
      OPEN(UNIT=9,FILE='ROWS.DAT',STATUS='OLD')
      OPEN(UNIT=10,FILE='RHS.DAT',STATUS='OLD')
C
C     OPEN THE FILE WHICH WILL ULTIMATELY CONTAIN THE PROPERLY
C     FORMATTED DATA SET.
C
      OPEN(UNIT=7,FILE='MPSIN.DAT',STATUS='NEW')
C
C     WRITE A RECORD TO THE FILE WHICH NAMES THE MPS FILE
C
      WRITE(7,299)
C
C     FIRST FORMAT THE ROWS.DAT FILE
C     THE FIRST RECORD IS A CHARACTER NAMING THE FILE ('ROWS')
C
      READ(9,300)NAME
      WRITE(7,300)NAME
C
C     THE SECOND RECORD IS THE CHARACTERS IDENTIFYING THE
C     OBJECTIVE FUNCTION
C
      READ(9,301)OBFUN
      WRITE(7,301)OBFUN
C     READ ALL ROWS (CORRESPOND TO CONSTRAINTS)
C     DELETE ANY BLANKS FROM THE NAME FIELD
C
      DO 350 I=2,MAXNOD+42
         READ(9,302)VAR,NODES

      DO 340 J=2,5
           IF(NODES(J:J).EQ.' ') NODES(J:J)='0'
 340     CONTINUE
         WRITE(7,302)VAR,NODES
 350  CONTINUE
C
C     NEXT FORMAT THE COLUMNS.DAT FILE
C     THE FIRST RECORD IS A CHARACTER NAMING THE FILE ('COLUMNS')
C
      READ(8,300)NAME
      WRITE(7,300)NAME
```

```
C
C     READ ALL COLUMNS (CORRESPOND TO VARIABLE DEFINITIONS)
C     DELETE ANY BLANKS FROM THE NAME FIELD FOR THE VARIABLE AND
C     ALSO FROM THE NAME FIELDS OF THE CORRESPONDING CONSTRAINTS
C
 355  CONTINUE
      READ(8,304,END=356)VARNAM,NODES,COEF1,NODES1,COEF2
      DO 310 J=2,5
         IF(VARNAM(J:J).EQ.' ') VARNAM(J:J) = '0'
 310  CONTINUE
      DO 315 J=2,5
         IF(NODES(J:J).EQ.' ') NODES(J:J)='0'
 315  CONTINUE
      IF(NODES1(1:1).NE.' ') THEN
         DO 318 J=2,5
            IF(NODES1(J:J).EQ.' ') NODES1(J:J)='0'
 318     CONTINUE
      ENDIF
      WRITE(7,304)VARNAM,NODES,COEF1,NODES1,COEF2
      GOTO 355
 356  CONTINUE
C
C     NEXT FORMAT THE RHS.DAT FILE
C     THE FIRST RECORD IS A CHARACTER NAMING THE FILE ('RHS')
C
      READ(10,300)NAME
      WRITE(7,300)NAME
C
C     READ ALL RECORDS (EACH RECORD CONTAINS RHS)
C     IN ALL THE NAME FIELDS REPLACE ALL BLANKS WITH ZEROS
C
 370  CONTINUE
      READ(10,304,END=375)RHSNAM,NODES,COEF1,NODES1,COEF2
      DO 371 J=2,5
         IF(NODES(J:J).EQ.' ')NODES(J:J)='0'
 371  CONTINUE
      IF(NODES1(1:1).NE.' ')THEN
         DO 372 J=2,5
            IF(NODES1(J:J).EQ.' ')NODES1(J:J)='0'
 372     CONTINUE
      ENDIF
      WRITE(7,304)RHSNAM,NODES,COEF1,NODES1,COEF2
      GOTO 370
 375  CONTINUE
C
C     WRITE 'ENDATA' TO END OF FILE
C
      WRITE(7,305)
      CLOSE(UNIT=7)
      CLOSE(UNIT=8)
```

```
      CLOSE(UNIT=9)
      CLOSE(UNIT=10)
C
 299  FORMAT('NAME',10X,'RATED')
 300  FORMAT(A7)
 301  FORMAT(A11)
 302  FORMAT(1X,A1,2X,A6)
 304  FORMAT(4X,A6,4X,A6,4X,A12,3X,A6,4X,A12)
 305  FORMAT('ENDATA')
      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C       SUBROUTINE OUTPUT
C       THIS PROGRAM READS THE DATA IN THE SOLUTION FILE CREATED
C       BY MINOS AND PRODUCES USEABLE OUTPUT.
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      SUBROUTINE OUTPUT
C
      COMMON/FIRST/MAXNOD,MAXFLOW,RQMT,FLOW,ATR,ASDSUM,MODTIME
      COMMON/FIRST/FAIP
      INTEGER RQMT(1:20,1:4),LEVEL(1:4,1:20)
      INTEGER CALCASD,CALCFLY,CALCTIM,FY,COUNT
      INTEGER ASDYG,CHECK,DUTY,ENDDUT,ENDTIM,FLOWNUM,FLYCRE
      INTFGER GATE,MINFLY,MAXFLY,MODTIME,NEWASD,NEWFLY,POS,TIME
      INTEGER TTIME,VARNUM,TAFSCD,TEMP,ASDGRP,GATSTAT,FLY,POINT
      INTEGER POWER
      INTEGER GATES(0:3,70:98)
      INTEGER FAIP(1:20)
      REAL TASSIGN(4),GTOTAL,TOTAL
C
      REAL ACTIVITY,ATRN
      REAL OUTPUT1(1:20,1:21,1:11,1:4)
      REAL OUTPUT2(1:3)
      REAL OUTPUT4(1:20,1:42,1:4)
      REAL OUTPUT5(1:20,1:42,1:4)
      REAL ASDSUM(1:4,0:36)
      REAL ATR(1:20,0:42)
      INTEGER FLOW(1:50000,1:13)
      REAL NASDSUM(0:20,1:4,0:36),NUMASGN(1:20,1:4,1:36)
C
      CHARACTER*3 STATE
C
      OPEN(UNIT=6,FILE='SOL.DAT',STATUS='OLD')
      OPEN(UNIT=7,FILE='GATES.DAT',STATUS='NEW')
      OPEN(UNIT=8,FILE='OUTPUT.DAT',STATUS='NEW')
      OPEN(UNIT=10,FILE='CHART.DAT',STATUS='NEW')
```

```
C
C     SOL.DAT CONTAINS THE MINOS SOLUTION DATA
C     THE ARRAY FLOW WAS CREATED BY THE MPSIN SUBROUTINE AND IT
C     CONTAINS FOR EACH VARIABLE THE FOLLOWING INFORMATION:
C        VARIABLE NUMBER, TIME OF BEGINNING AND ENDING NODE,
C        ASD AT BEGINNING AND ENDING NODE, FLYING CREDIT AT
C        BEGINNING AND ENDING NODE, DUTY TYPE AT BEGINNING AND
C        ENDING NODE, AND THE TYPE OF GATE NON-ACHIEVEMENT THE
C        FLOW LEADS TO (IF ANY)
C
C        FLOW(FLOWNUM,1) = BEGINNING NODE
C        FLOW(FLOWNUM,2) = ENDING NODE
C        FLOW(FLOWNUM,3) = RETENTION WHICH OCCURS ALONG ARC
C        FLOW(FLOWNUM,4) = TIME AT START OF ARC
C        FLOW(FLOWNUM,5) = TIME AT END OF ARC
C        FLOW(FLOWNUM,6) = ASD AT START OF ARC
C        FLOW(FLOWNUM,7) = ASD AT END OF ARC
C        FLOW(FLOWNUM,8) = FLYING CREDIT AT START OF ARC
C        FLOW(FLOWNUM,9) = FLYING CREDIT AT END OF ARC
C        FLOW(FLOWNUM,11) = DUTY AT START OF ARC
C        FLOW(FLOWNUM,12) = DUTY AT END OF ARC
C        FLOW(FLOWNUM,13) = GATE WHICH THIS FLOW CONTRIBUTES TO
C                           (IF ANY)
C
C     INITIALIZE SOME PARAMETERS AND COUNTERS
C
      COUNT=0
      FLAG=0
      DO 300 I=1,3
         OUTPUT2(I)=0.0
 300  CONTINUE
C
C     IGNORE THE FIRST 14 RECORDS IN SOL.DAT BECAUSE THEY CONTAIN
C     GENERAL PROGRAM INFORMATION
C
      DO 425 I=1,14
         READ(6,600)CHECK
 425  CONTINUE
C
C     READ THROUGH THE ROWS SECTION IN THE SOLUTION FILE UNTIL
C     FINDING A RECORD THAT STARTS WITH A 1 AND IS OTHERWISE
C     BLANK.  THIS RECORD MARKS THE END OF THE ROWS SECTION.
C
 450  CONTINUE
      READ(6,600)CHECK
      IF(CHECK.NE.1)GOTO 450
C
C     IF CHECK IS 1 THEN SKIP THE NEXT 4 RECORDS AND THEN BEGIN
C     READING THE COLUMN DATA.
C
```

```
      DO 460 I=1,4
         READ(6,600)CHECK
 460  CONTINUE
C
C
 500  CONTINUE
      READ(6,601,END=590)VARNUM,STATE,ACTIVITY
C
C     IF STATE IS A 'B' THEN THIS VARIABLE IS A BASIC (BS) OR
C     SUPERBASIC (SBS) VARIABLE.
C
      IF(STATE(2:2).EQ.'B')THEN
C
C     SEARCH THE ARRAY FLOW FOR THIS VARIABLE.
C
C     CHECK FIRST TO SEE IF THE NEXT RECORD IN FLOW IS THE RECORD
C     FOR A DEVIATION VARIABLE.  IF SO, VARNUM WILL BE LARGER
C     THAN THE VARIABLE MAXFLOW.  MAXFLOW HOLDS THE NUMBER OF THE
C     LAST NODAL CONSERVATION CONSTRAINT.
C
C     THERE ARE 2 DEVIATION VARIABLES FOR EACH MANNING LEVEL
C     CONSTRAINT IN ARRAY FLOW AND IN SOL.DAT.  THE FORMAT IS
C     SUCH THAT THE POSITIVE DEVIAITON VARIABLE IS FIRST,
C     FOLLOWED BY THE NEGATIVE DEVIATION VARIABLE.
C     AFTER FINDING THE FIRST DEVIATION VARIABLE IN THE ARRAY
C     FLOW, SET POS=1 TO INDICATE WHICH DEV. VARIABLE WE ARE
C     CURRENTLY COMPARING.
C
 525  CONTINUE
         TIME=FLOW(VARNUM,4)
         ENDTIM=FLOW(VARNUM,5)
         IF(ENDTIM.EQ.0.AND.TIME.EQ.0)THEN
            IF(FLAG.EQ.0)THEN
               FLAG=1
               POS=1
               FLOWNUM=MAXFLOW+1
               TTIME=1
               COUNT=1
            ENDIF
C
C     IN SOL.DAT, THE DEVIATON VARIABLES RUN
C     FOR EACH TIME PERIOD THE 4 DUTY TYPES.
C     COUNT WILL BE INCREMENTED AFTER THE NEGATIVE DEVIATION
C     VARIABLE HAS BEEN PROCESSED.
C     WHEN COUNT REACHES FOUR, INCREMENT TTIME TO THE NEXT LEVEL
C     OF TIME.
C
C     IF FLOW(VARNUM,6)=50 THEN THIS VARIABLE IS ONE OF THE FLOWS
C     LEADING TO THE SINK NODE.  DO NOT PROCESS IT!
C
```

```
            IF(FLOW(VARNUM,6).EQ.50)GOTO 500
            IF(VARNUM.NE.FLOWNUM)THEN
               FLOWNUM=FLOWNUM+1
C
C     IF POS=0 THEN WE ARE PROCESSING THE NEGATIVE DEV.VARIABLE
C
               IF(POS.EQ.0)THEN
                  POS=1
                  COUNT=COUNT+1
                  IF(COUNT.GT.4)THEN
                     COUNT=1
                     TTIME=TTIME+1
                  ENDIF
                  GOTO 525
               ENDIF
C
C     IF POS=1 THEN WE ARE PROCESSING THE POSITIVE DEV. VARIABLE

C
               IF(POS.EQ.1)THEN
                  POS=0
                  GOTO 525
               ENDIF
            ENDIF
            IF(VARNUM.EQ.FLOWNUM)THEN
               FLOWNUM=FLOWNUM+1
               IF(POS.EQ.1)THEN
                  LEVEL(COUNT,TTIME)=ACTIVITY
                  POS=0
                  GOTO 500
               ENDIF
               IF(POS.EQ.0)THEN
                  LEVEL(COUNT,TTIME)=0-ACTIVITY
                  POS=1
                  COUNT=COUNT+1
                  IF(COUNT.GT.4)THEN
                     COUNT=1
                     TTIME=TTIME+1
                  ENDIF
                  GOTO 500
               ENDIF
            ENDIF
         ENDIF
C
C
C
C     CONVERT TIME FROM HALF YEAR INCREMENTS TO FULL YEAR
C     INCREMENTS
C
         IF(ENDTIM.EQ.0.AND.TIME.EQ.0)GOTO 500
```

```
         IF(ENDTIM.GT.MODTIME)ENDTIM=MODTIME
         CALCTIM=INT((TIME+1)/2)
C
C     FIND THE PROPER FLYING GATE INTERVAL IN WHICH FLYCRE
C     BELONGS.  FLYING GATE INTERVALS ARE IN YEARS
C
         CALCFLY=INT((FLOW(VARNUM,8)+1)/2)
C
C     CONVERT ASDYG INTO YEARS
C
         CALCASD=INT((FLOW(VARNUM,6)+1)/2)
C
C      OUTPUT 1 IS THE ARRAY WHICH PRINTS FOR EACH SPECIFIC TIME
C      PERIOD THE FOLLOWING INFORMATION:
C
C      FOR EACH ASD YEAR GROUP (1-21) AND GATE, AN OPTIMAL FLOW
C      IS PROVIDED FOR EVERY POSSIBLE FLOW.
C
         ENDDUT=FLOW(VARNUM,12)
         DUTY=FLOW(VARNUM,11)
         OUTPUT1(CALCTIM,CALCASD,CALCFLY,ENDDUT)=OUTPUT1(CALCTIM
     +   ,CALCASD,CALCFLY,ENDDUT)+ACTIVITY
C
C     OUTPUT2 IS THE ARRAY WHICH HOLDS THE TOTAL NUMBER, FOR EACH
C     FLYING GATE MISSED.
C     IF FLOW(VARNUM,13)  NOT EQUAL TO 0 THEN THIS VARIABLE LEADS
C     TO A NONACHIEVEMENT OF A FLYING GATE AND SHOULD BE STORED
C     IN THE APPROPRIATE ELEMENT OF OUTPUT2
C
         IF(FLOW(VARNUM,13).NE.0)THEN
            GATE=FLOW(VARNUM,13)
            OUTPUT2(GATE)=OUTPUT2(GATE)+ACTIVITY
         ENDIF
C
C     MUST WRITE OUT THE APPROPRIATE INFORMATION TO THE ARRAYS
C     OUTPUT4 AND OUTPUT5.
C     OUTPUT4(TIME,NEWASD-ENDTIM,ENDDUT) CONTAINS THE NUMBER
C     OF INDIVIDUALS WHO ROTATE INTO THE DUTY TYPE 'ENDDUT'
C
C     OUTPUT5(TIME,NEWASD-ENDTIM,DUTY) CONTAINS THE NUMBER
C     OF INDIVIDUALS WHO ROTATE OUT OF THE DUTY TYPE 'DUTY'
C
C     IGNORE ANY FLOWS WHICH LEAD TO A SINK NODE.  THESE NODES
C     ARE IDENTIFIED IF THEIR ENDING NODE IS GREATER THAN MAXNOD
C     IF(FLOW(VARNUM,2) > MAXNOD)
         IF(FLOW(VARNUM,2).LE.MAXNOD)THEN
            IF(DUTY.NE.ENDDUT) THEN
               IF(FLOW(VARNUM,7)-ENDTIM.GT.0)THEN
                OUTPUT4(TIME,FLOW(VARNUM,7)-ENDTIM,ENDDUT)=
     +          OUTPUT4(TIME,FLOW(VARNUM,7)-ENDTIM,ENDDUT)
```

```
     +           +ACTIVITY
                 OUTPUT5(TIME,FLOW(VARNUM,7)-ENDTIM,DUTY)=
     +           OUTPUT5(TIME,FLOW(VARNUM,7)-ENDTIM,DUTY)+ACTIVITY

                ENDIF
             ENDIF
          ENDIF
C
C       THIS SECTION OF CODE WILL BUILD THE ARRAY
C       GATES(GATSTAT,DATE).  THIS ARRAY WILL HOLD HOW MANY
C       INDIVIDUALS HAVE MET EACH GATE AT A SPECIFIC TIME PERIOD
C       DESIGNATED BY THE USER
C
C       FIRST SELECT THE TIME PERIOD OF INTEREST
C       THIS SHOULD BE IN HALF-YEAR INCREMENTS
C       FOR EXAMPLE:  POINT=10 IS (10/2) = 5 YEARS.
C
          POINT=10
C
C       AS WE FIND BASIC VARIABLES IN THE SOLUTION FILE, DETERMINE
C       WHAT (IF ANY) CONTRIBUTION THEY MAKE TO THE GATES ARRAY
C       BASED ON THE POINT IN TIME WE ARE INTERESTED IN.
C
C       EACH BASIC VARIABLE HAS CORRESPONDING ENTRIES IN THE ARRAY
C       FLOW AS DESCRIBED ABOVE.
C
C       EACH DUTY HAS A DIFFERENT DURATION WHICH IS SELECTED BY THE
C       USER IN THE SUBROUTINE MPSIN.  IF THES FLOW (ASSIGNMENT)
C       STARTED BEFORE "POINT" AND ENDS AFTER "POINT" THEN THE
C       NUMBERS FOUND IN ACTIVITY CONTRIBUTE TO THE ARRAY GATES.
C
        IF(FLOW(VARNUM,4).LT.POINT.AND.FLOW(VARNUM,5).GE.POINT)THEN

C
C       NOW MUST FIND OUT WHAT THE FLYING CREDIT ACCUMULATION IS
C       FOR THIS GROUP AT THE TIME "POINT".  FLOW(VARNUM,8)CONTAINS
C       THE FLYING CREDIT AT THE SOURCE NODE.  IF DUTY IS 1 (OPS)
C       THEN THIS MUST BE INCREMENTED TO REFLECT A NEW TOTAL AT
C       TIME PERIOD "POINT".  IF DUTY NOT EQUAL TO 1, THEN THIS IS
C       THE FLYING CREDIT ACCUMULATED.
C
          IF(FLOW(VARNUM,12).EQ.1)FLY=FLOW(VARNUM,8)+(POINT-
     +    FLOW(VARNUM,4))
          IF(FLOW(VARNUM,12).NE.1)FLY=FLOW(VARNUM,8)
C
C       NOW MUST CONVERT THE VARIABLE FLY INTO A CORRESPONDING
C       REPRESENTATION OF A "GATE" STATUS.  FLY<12 IS GATE 0,
C       12<=FLY<18 IS GATE 1, ETC.
C
          IF(FLY.GE.22)GATSTAT=3
```

```
            IF(FLY.GE.18.AND.FLY.LT.22)GATSTAT=2
            IF(FLY.GE.12.AND.FLY.LT.18)GATSTAT=1
            IF(FLY.LT.12)GATSTAT=0
C
C     NOW MUST DETERMINE WHAT ASDYG THIS VARIABLE BELONG TO.
C     TO DETERMINE THIS, FIND THE ASDYG AT THE SOURCE NODE AND
C     SUBT. HOW MANY TIME PERIODS HAVE PASSED TO REACH "POINT".
C     THIS IS THE ASDYG IN HALF-YEAR INCREMENTS TO FIND WHAT YEAR
C     THIS GROUP STARTED FLYING -CONVERT TO FULL YEAR INCREMENTS
C     AND SUBTRACT FROM THE STARTING YEAR OF THE MODEL.
C
            TEMP=FLOW(VARNUM,6)-FLOW(VARNUM,4)
C
C     CONVERT TO FULL YEAR
C
            ASDGRP=INT((TEMP+1)/2)
            TAFSCD=88-ASDGRP
C
C     NOW ENTER THIS VARIABLE INTO ITS PROPER POSITION IN GATES
C     ARRAY.  MUST TAKE INTO ACCOUNT THE ATTRITION OCCURING
C     ACROSS THE FLOWS.
C     IF DUTY IS PME OR AFIT, THEN NO ATTRITION OCCURS.
            IF(FLOW(VARNUM,6).GT.42)FLOW(VARNUM,6)=42
C
            IF(DUTY.EQ.3.OR.DUTY.EQ.4)GATES(GATSTAT,TAFSCD)=GATES
     +      (GATSTAT,TAFSCD)+ACTIVITY
C
C      IF DUTY IS OPS OR SUP THEN ATTRITION OCCURES EVERY YEAR
C
            IF(DUTY.EQ.1.OR.DUTY.EQ.2)THEN
               POWER=INT((POINT-FLOW(VARNUM,4)+1)/2)
               TEMP=(ASDGRP*2)+POINT
               IF(TEMP.GT.42)TEMP=42
               ATRN=ATR((POINT,TEMP))**POWER
               GATES(GATSTAT,TAFSCD)=GATES(GATSTAT,TAFSCD)+ACTIVITY
     +         *ATRN
            ENDIF
          ENDIF
        ENDIF
        GOTO 500
 590    CONTINUE
C
C
C     NOW WRITE ALL THIS INFORMATION TO THE FILE 'OUTPUT.DAT'
C
C     WRITE THE INFORMATION FOUND IN OUTPUT1
C
      FY=88
      DO 660 TIME=1,1
         WRITE(8,621)FY
```

```
          DO 650 CALCASD=1,21
          IF(CALCASD.LT.6)THEN
            MINFLY=CALCASD
          ELSE
            MINFLY=6
          ENDIF
          IF(CALCASD.GT.11)THEN
             MAXFLY=11
          ELSE
             MAXFLY=CALCASD
          ENDIF
          DO 650 CALCFLY=MINFLY,MAXFLY
            TOTAL=OUTPUT1(TIME,CALCASD,CALCFLY,1)+OUTPUT1(
     +      TIME,CALCASD,CALCFLY,2)+OUTPUT1(TIME,CALCASD,
     +      CALCFLY,3)+OUTPUT1(TIME,CALCASD,CALCFLY,4)
            WRITE(8,622)CALCASD,CALCFLY,OUTPUT1(TIME,CALCASD,
     +      CALCFLY,1),OUTPUT1(TIME,CALCASD,CALCFLY,2),
     +      OUTPUT1(TIME,CALCASD,CALCFLY,3),OUTPUT1(TIME,
     +      CALCASD,CALCFLY,4),TOTAL
C
            TASSIGN(1)=TASSIGN(1)+OUTPUT1(TIME,CALCASD,
     +      CALCFLY,1)
            TASSIGN(2)=TASSIGN(2)+OUTPUT1(TIME,CALCASD,
     +      CALCFLY,2)
            TASSIGN(3)=TASSIGN(3)+OUTPUT1(TIME,CALCASD,
     +      CALCFLY,3)
            TASSIGN(4)=TASSIGN(4)+OUTPUT1(TIME,CALCASD,
     +      CALCFLY,4)
C
 650      CONTINUE
C
       GTOTAL=TASSIGN(1)+TASSIGN(2)+TASSIGN(3)+TASSIGN(4)
       WRITE(8,623)TASSIGN(1),TASSIGN(2),TASSIGN(3),TASSIGN(4),
     +GTOTAL
       FY=FY+1
 660   CONTINUE
C
C      WRITE THE INFORMATION FOUND IN OUTPUT2
C
       WRITE(8,610)
       WRITE(8,611)' 1ST GATE',OUTPUT2(1)
       WRITE(8,611)' 2ND GATE',OUTPUT2(2)
       WRITE(8,611)' 3RD GATE',OUTPUT2(3)
C
C
C      WRITE OUT THE INFORMATION IN THE ARRAY LEVEL
C
       DO 570 DUTY=1,4
          WRITE(8,624)DUTY
          FY=88
```

```
          WRITE(8,625)FY,RQMT(1,DUTY),RQMT(2,DUTY),
     +    RQMT(1,DUTY)-LEVEL(DUTY,1),RQMT(2,DUTY)-LEVEL(DUTY,2)
          FY=FY+1
          WRITE(8,625)FY,RQMT(3,DUTY),RQMT(4,DUTY),
     +    RQMT(3,DUTY)-LEVEL(DUTY,3),RQMT(4,DUTY)-LEVEL(DUTY,4)
          FY=FY+1
          WRITE(8,625)FY,RQMT(5,DUTY),RQMT(6,DUTY),
     +    RQMT(5,DUTY)-LEVEL(DUTY,5),RQMT(6,DUTY)-LEVEL(DUTY,6)
          FY=FY+1
          WRITE(8,625)FY,RQMT(7,DUTY),RQMT(8,DUTY),
     +    RQMT(7,DUTY)-LEVEL(DUTY,7),RQMT(8,DUTY)-LEVEL(DUTY,8)
          FY=FY+1
          WRITE(8,625)FY,RQMT(9,DUTY),RQMT(10,DUTY),
     +    RQMT(9,DUTY)-LEVEL(DUTY,9),RQMT(10,DUTY)-LEVEL(DUTY,10)

          FY=FY+1
          WRITE(8,625)FY,RQMT(11,DUTY),RQMT(12,DUTY),
     +    RQMT(11,DUTY)-LEVEL(DUTY,11),RQMT(12,DUTY)
     +    -LEVEL(DUTY,12)
          FY=FY+1
          WRITE(8,625)FY,RQMT(13,DUTY),RQMT(14,DUTY),
     +    RQMT(13,DUTY)-LEVEL(DUTY,13),RQMT(14,DUTY)
     +    -LEVEL(DUTY,14)
 570  CONTINUE
C
C
C     THIS SECTION WILL PRODUCE THE DATA WHICH WILL BE WRITTEN TO
C     A SAS INPUT FILE.  THIS DATA, ONCE PROCESSED BY SAS, WILL
C     PRODUCE A PLOT FOR EACH ENTERING ASD YEAR GROUP THAT WILL
C     CONTAIN THE FOLLOWING:
C           FOR EACH YEAR OF THE MODEL, THE PERCENTAGE OF EACH
C           DUTY TYPE PRESENT
C
      COUNT=8
      DO 810 ASDYG=1,28
            DO 810 DUTY=1,4
              TIME=0
C
C     ASDSUM HOLDS THE INITIAL SETUP OF THE ASD YEAR GROUP
C
              NASDSUM(0,DUTY,ASDYG)=ASDSUM(DUTY,ASDYG)
C
C     FOR ASDYG 1, 2, 3, AND 4 MUST ADD THE "FUTURE" MANPOWER
C     ADDITIONS THESE ASD YEAR GROUPS GET FROM FAIP ACCESSIONS.
C
              IF(ASDYG.LE.8)THEN
                 IF(DUTY.EQ.1)THEN
                   NASDSUM(0,DUTY,ASDYG)=NASDSUM(0,DUTY,ASDYG)+
     +             FAIP(COUNT)
                   COUNT=COUNT-1
```

```
                 ENDIF
              ENDIF
              IF(NASDSUM(0,DUTY,ASDYG).NE.0)
     +        WRITE(10,627)NASDSUM(0,DUTY,ASDYG),TIME,DUTY,ASDYG
C
C     NOW MUST DETERMINE HOW THE ASDYG CHANGES AS TIME PROGRESSES
C     FOR EACH TIME PERIOD (IN FULL YEARS), THE ASDYG WILL HAVE
C     A DIFFERENT DISTRIBUTION OF INDIVIDUALS IN EACH DUTY.
C
              DO 810 TIME=1,14
C
C     NUMASGN HOLDS THE VALUE OF HOW MANY INDIVIDUALS ARE
C     ASSIGNED TO A PACTICULAR DUTY IN A SPECIFIC TIME PERIOD.
C     OUTPUT4 IS HOW MANY INDIVIDUALS ARE ASSIGNED TO THE DUTY
C     TYPE.
C     OUTPUT5 IS HOW MANY INDIVIDUALS ARE ASSIGNED OUT OF THE
C     DUTY TYPE.
C     BOTH OUTPUT4 AND OUTPUT5 ARE IN TERMS OF HALF-YEARS
C
C     ATTRITION ONLY OCCURS FOR DUTY TYPES OPS (1) AND SUP(2)
C
                 IF(DUTY.EQ.1.OR.DUTY.EQ.2) THEN
                    NUMASGN(TIME,DUTY,ASDYG)=
     +              OUTPUT4(TIME,ASDYG,DUTY)*ATR(TIME,ASDYG)-
     +              OUTPUT5(TIME,ASDYG,DUTY)
                 ENDIF
C
C     ATTRITION DOES NOT OCCUR FOR DUTY TYPES AFIT (3) OR PME (4)
C
                 IF(DUTY.EQ.3.OR.DUTY.EQ.4)THEN
                    NUMASGN(TIME,DUTY,ASDYG)=
     +              OUTPUT4(TIME,ASDYG,DUTY)-
     +              OUTPUT5(TIME,ASDYG,DUTY)
                 ENDIF
C
C     THE TOTAL NUMBER OF INDIVIDUALS NOW ASSIGNED TO THE
C     ASDYG,DUTY COMBINATION IS THE PREVIOUS NASDSUM+NUMASGN
C
                 NASDSUM(TIME,DUTY,ASDYG)=NASDSUM(TIME-1,DUTY,
     +           ASDYG)+NUMASGN(TIME,DUTY,ASDYG)
                 IF(NASDSUM(TIME,DUTY,ASDYG).GT.0)WRITE
     +           (10,627)NASDSUM(TIME,DUTY,ASDYG),TIME,DUTY,ASDYG
C
C     THE FOLLOWING SECTION CREATES A DATA FILE WHICH CONTAINS
C     FOR EACH TAFSCD THE NUMBER OF PILOTS WHO HAVE MET CORRES-
C     PONDING FLIGHT GATES.
C     THIS DATA FILE WILL THEN BE INPUT TO AN APPROPRIATE SAS
C     PROGRAM WHICH WILL PRODUCE A CHART REPRESENTING THE FLIGHT
C     GATE DISTRIBUTION.
C
```

```
810   CONTINUE
      DO 910 TAFSCD=70,88
         DO 910 GATSTAT=0,3
            WRITE(7,630)GATES(GATSTAT,TAFSCD),TAFSCD,GATSTAT
910   CONTINUE
      CLOSE(UNIT=6)
      CLOSE(UNIT=7)
      CLOSE(UNIT=8)
      CLOSE(UNIT=10)
600   FORMAT(I1)
601   FORMAT(11X,I5,5X,A3,4X,E16.6)
602   FORMAT(I5,6(2X,I2),3(2X,I1))
610   FORMAT(//,22X,'DISTRIBUTION OF MISSED FLYING GATES')
611   FORMAT(' ',A8,10X,F7.2)
614   FORMAT(' ',2X,I2,3X,F7.2,2(3X,F7.2),2X,'*',F7.2,5(3X,F7.2))
615   FORMAT(' ',2X,I2,3X,F7.2,3(3X,F7.2),2X,'*',F7.2,4(3X,F7.2))
616   FORMAT(' ',2X,I2,3X,F7.2,3(3X,F7.2),2X,'$',F7.2,2X,'*'
     +,F7.2,3(3X,F7.2))
617   FORMAT(' ',2X,I2,3X,F7.2,4(3X,F7.2),2X,'$',F7.2,2X,'*'
     +,F7.2,2(3X,F7.2))
618   FORMAT(' ',2X,I2,3X,F7.2,5(3X,F7.2),2X,'$',F7.2,2X,'*'
     +,F7.2,3X,F7.2)
619   FORMAT(' ',2X,I2,3X,F7.2,2(3X,F7.2),5(2X,'!',F7.2),3X,F7.2)
620   FORMAT(' ','*  INDICATES MUST FLY'/' $  INDICATES WILL
     +' MISS GATE'/' !  INDICATES MISSED GATE')
621   FORMAT('1',//,' OPTIMAL ASSIGNMENTS FOR FISCAL YEAR  ',
     +I3//'  ASD  GATE  '35X,'TOTAL'/
     +'  YEAR  TIME     FLY          SUP          AFIT
     +'PME          ASSIGN'/)
622   FORMAT('  ',I3,2X,I3,3X,4(F7.2,5X),F8.2)
623   FORMAT(' ',/'  TOTAL',5X,4(F8.2,4X),F8.2)
624   FORMAT(' ',9X,'DUTY TYPE ',I2,' '/
     +' YEAR',5X,'DESIRABLE',5X,'ACTUAL'/
     +' ',9X,'1ST  2ND ',6X,'1ST  2ND'/
     +' ----',4X,'----------',6X,'----------')
625   FORMAT(' ',I4,3X,I4,2X,I4,6X,I4,2X,I4)
626   FORMAT(F7.2)
627   FORMAT(f8.3,2X,I2,2X,I2,I3)
628   FORMAT(F6.4)
630   FORMAT(I4,I3,I2)
      RETURN
      END
```

APPENDIX C

Example of Output From INPUT.DAT

INPUT PARAMETERS

DUTY TYPE:	FLY	SUP	AFIT	PME
duty duration:	4	4	1	1

DUTY COMPOSITION STATISTICS
NOTE: these figures represent the situation after the model has forced certain duty,ASD, and gate creditcombinations (columns sum to 100 percent)

type that belong to each asd group

asd group	fly	sup	afit	pme
1.0	0.	0.	0.	0.
1.0	0.	0.	0.	0.
2.0	0.	0.	0.	0.
2.0	1.	0.	0.	0.
3.0	4.	0.	0.	0.
3.0	5.	0.	0.	0.
4.0	4.	0.	0.	0.
4.0	6.	0.	0.	0.
5.0	6.	0.	0.	0.
5.0	11.	0.	0.	0.
6.0	5.	1.	0.	0.
6.0	11.	0.	0.	0.
7.0	7.	0.	0.	0.
7.0	8.	0.	0.	0.
8.0	4.	0.	6.	0.
8.0	2.	2.	17.	0.
9.0	3.	2.	22.	0.
9.0	2.	4.	17.	0.
10.0	1.	7.	11.	0.
10.0	1.	4.	0.	0.
11.0	1.	2.	6.	0.
11.0	0.	5.	6.	0.
12.0	1.	2.	0.	0.
12.0	1.	6.	17.	0.
13.0	1.	4.	0.	0.
13.0	1.	4.	0.	0.
14.0	1.	5.	0.	0.
14.0	2.	8.	0.	0.
15.0	1.	7.	0.	0.
15.0	1.	6.	0.	0.
16.0	1.	5.	0.	0.
16.0	1.	9.	0.	0.
17.0	2.	4.	0.	0.
17.0	2.	8.	0.	0.
18.0	2.	4.	0.	0.

Percent of total personnel in each
asd group that are in each duty type

asd group	fly	sup	afit	pme
1.0	0.	0.	0.	0.
1.0	0.	0.	0.	0.
2.0	0.	0.	0.	0.
2.0	100.	0.	0.	0.
3.0	100.	0.	0.	0.
3.0	100.	0.	0.	0.
4.0	100.	0.	0.	0.
4.0	100.	0.	0.	0.
5.0	100.	0.	0.	0.
5.0	100.	0.	0.	0.
6.0	98.	2.	0.	0.
6.0	100.	0.	0.	0.
7.0	100.	0.	0.	0.
7.0	100.	0.	0.	0.
8.0	97.	0.	3.	0.
8.0	81.	7.	11.	0.
9.0	80.	9.	11.	0.
9.0	74.	16.	10.	0.
10.0	54.	38.	8.	0.
10.0	55.	45.	0.	0.
11.0	80.	13.	7.	0.
11.0	36.	55.	9.	0.
12.0	73.	27.	0.	0.
12.0	50.	36.	14.	0.
13.0	50.	50.	0.	0.
13.0	50.	50.	0.	0.
14.0	60.	40.	0.	0.
14.0	69.	31.	0.	0.
15.0	59.	41.	0.	0.
15.0	62.	38.	0.	0.
16.0	60.	40.	0.	0.
16.0	54.	46.	0.	0.
17.0	77.	23.	0.	0.
17.0	68.	32.	0.	0.
18.0	75.	25.	0.	0.

ASD GROUP COMPOSITION STATISTICS
NOTE: These numbers are after the model
has forced certain combinations
(rows sum to 100 percent)

% of each asd group by gate credit accumulated

asd group	6 yrs		7 yrs		8 yrs		9 yrs		10 yrs		11 yrs	
6.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6.0	0.	71.	29.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7.0	0.	1.	49.	50.	0.	0.	0.	0.	0.	0.	0.	0.
7.0	0.	1.	3.	61.	36.	0.	0.	0.	0.	0.	0.	0.
8.0	0.	0.	8.	0.	64.	28.	0.	0.	0.	0.	0.	0.
8.0	0.	0.	15.	11.	7.	30.	37.	0.	0.	0.	0.	0.
9.0	0.	3.	3.	3.	11.	3.	54.	23.	0.	0.	0.	0.
9.0	0.	10.	3.	0.	13.	3.	6.	42.	23.	0.	0.	0.
10.0	0.	4.	0.	13.	8.	8.	21.	8.	29.	8.	0.	0.
10.0	0.	0.	0.	0.	18.	18.	9.	0.	9.	27.	18.	0.
11.0	0.	0.	0.	0.	13.	0.	7.	7.	13.	7.	33.	20.
11.0	0.	0.	9.	0.	18.	0.	18.	9.	9.	0.	0.	36.
12.0	0.	0.	0.	0.	9.	9.	18.	0.	9.	9.	9.	36.
12.0	0.	0.	5.	5.	5.	0.	5.	0.	9.	14.	14.	45.
13.0	0.	0.	0.	0.	10.	10.	0.	10.	0.	20.	0.	50.
13.0	0.	0.	0.	0.	0.	0.	0.	10.	10.	10.	20.	50.
14.0	0.	0.	0.	0.	0.	0.	0.	13.	7.	0.	0.	80.
14.0	0.	0.	0.	3.	0.	6.	6.	9.	6.	9.	6.	53.
15.0	0.	0.	0.	0.	0.	0.	0.	5.	5.	9.	18.	64.
15.0	0.	0.	0.	0.	0.	0.	0.	5.	0.	10.	14.	71.
16.0	0.	0.	0.	0.	0.	7.	7.	13.	0.	27.	0.	47.
16.0	0.	0.	0.	0.	4.	0.	0.	13.	8.	8.	0.	67.
17.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	23.	5.	73.
17.0	0.	0.	0.	0.	0.	0.	0.	0.	3.	6.	13.	77.
18.0	0.	0.	0.	0.	0.	0.	0.	5.	0.	0.	10.	85.

ARRIVED-STATION STATISTICS
Number that arrived at initial duty station
during indicated time periods.
1st column = fy 1st half, 2nd column = fy 2nd half

duty type	before FY84	FY84		FY85		FY86		FY87		total
1	63.	24.	58.	103.	165.	133.	216.	241.	209.	1212.
2	26.	4.	13.	7.	21.	22.	66.	34.	83.	276.
3	0.	0.	0.	1.	0.	0.	0.	0.	17.	18.
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	89	28	71	111	186	155	282	275	309	

TOTAL ROTATIONS grouped by "from" duty and "initial" asd group
each year has two half periods

YEAR	88		89		90		91		92	
DUTY 1; ASD 1.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 1; ASD 1.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 1; ASD 2.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 1; ASD 2.0	0.	0.	0.	0.	0.	0.	0.	0.	13.	0.
DUTY 1; ASD 3.0	0.	0.	0.	0.	0.	0.	0.	11.	32.	0.
DUTY 1; ASD 3.0	0.	0.	0.	0.	0.	0.	22.	22.	4.	0.
DUTY 1; ASD 4.0	0.	0.	0.	0.	1.	13.	25.	1.	4.	0.
DUTY 1; ASD 4.0	0.	0.	0.	0.	24.	26.	6.	3.	4.	0.
DUTY 1; ASD 5.0	0.	0.	1.	25.	24.	1.	0.	4.	9.	0.
DUTY 1; ASD 5.0	0.	1.	21.	36.	2.	1.	5.	23.	21.	0.
DUTY 1; ASD 6.0	0.	5.	9.	1.	0.	3.	5.	5.	19.	0.
DUTY 1; ASD 6.0	9.	10.	1.	1.	6.	9.	11.	44.	17.	0.
DUTY 1; ASD 7.0	7.	0.	0.	1.	7.	9.	22.	21.	3.	0.
DUTY 1; ASD 7.0	2.	0.	3.	4.	5.	21.	12.	15.	14.	0.
DUTY 1; ASD 8.0	0.	0.	0.	0.	13.	7.	9.	8.	1.	0.
DUTY 1; ASD 8.0	0.	0.	0.	3.	5.	1.	6.	6.	1.	0.
DUTY 1; ASD 9.0	0.	0.	1.	4.	5.	2.	4.	7.	5.	0.
DUTY 1; ASD 9.0	1.	1.	0.	0.	2.	4.	2.	5.	8.	0.
DUTY 1; ASD 10.0	0.	0.	0.	1.	2.	3.	2.	4.	1.	0.
DUTY 1; ASD 10.0	0.	0.	0.	1.	1.	2.	1.	1.	0.	0.
DUTY 1; ASD 11.0	0.	0.	1.	0.	2.	0.	1.	7.	1.	0.
DUTY 1; ASD 11.0	0.	0.	1.	0.	1.	0.	0.	1.	1.	0.
DUTY 1; ASD 12.0	0.	0.	0.	1.	2.	0.	3.	2.	0.	0.
DUTY 1; ASD 12.0	0.	0.	0.	0.	2.	4.	2.	2.	1.	0.
DUTY 1; ASD 13.0	1.	0.	0.	0.	0.	0.	2.	0.	2.	0.
DUTY 1; ASD 13.0	0.	0.	0.	0.	1.	0.	1.	1.	2.	0.
DUTY 1; ASD 14.0	0.	1.	0.	2.	1.	1.	1.	1.	2.	0.
DUTY 1; ASD 14.0	2.	0.	1.	3.	4.	3.	4.	1.	4.	0.
DUTY 1; ASD 15.0	1.	0.	0.	2.	4.	0.	4.	1.	1.	0.
DUTY 1; ASD 15.0	0.	0.	0.	1.	2.	1.	7.	2.	0.	0.
DUTY 1; ASD 16.0	0.	1.	0.	1.	1.	1.	2.	2.	1.	0.
DUTY 1; ASD 16.0	4.	0.	1.	0.	2.	0.	1.	3.	2.	0.
DUTY 1; ASD 17.0	5.	0.	1.	2.	3.	0.	3.	0.	3.	0.
DUTY 1; ASD 17.0	2.	1.	2.	0.	7.	1.	3.	1.	4.	0.
DUTY 1; ASD 18.0	5.	0.	1.	1.	3.	1.	2.	1.	1.	0.
DUTY 2; ASD 1.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 1.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 2.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 2.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 3.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 3.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 4.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 4.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 5.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 5.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 6.0	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.
DUTY 2; ASD 6.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 7.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 7.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

DUTY 2; ASD 8.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 2; ASD 8.0	0.	0.	0.	0.	0.	0.	0.	1.	1.	0.
DUTY 2; ASD 9.0	0.	0.	0.	0.	0.	0.	1.	0.	2.	0.
DUTY 2; ASD 9.0	0.	0.	0.	0.	1.	2.	1.	0.	1.	0.
DUTY 2; ASD 10.0	0.	0.	0.	0.	1.	3.	1.	1.	3.	0.
DUTY 2; ASD 10.0	0.	0.	0.	0.	0.	1.	2.	0.	2.	0.
DUTY 2; ASD 11.0	0.	0.	0.	0.	0.	1.	0.	0.	1.	0.
DUTY 2; ASD 11.0	0.	0.	0.	0.	0.	1.	1.	3.	1.	0.
DUTY 2; ASD 12.0	0.	0.	0.	1.	0.	0.	1.	0.	1.	0.
DUTY 2; ASD 12.0	0.	0.	0.	0.	2.	1.	4.	0.	1.	0.
DUTY 2; ASD 13.0	0.	0.	0.	0.	1.	1.	1.	0.	2.	0.
DUTY 2; ASD 13.0	0.	0.	0.	0.	0.	1.	2.	0.	2.	0.
DUTY 2; ASD 14.0	0.	0.	0.	0.	0.	0.	1.	0.	5.	0.
DUTY 2; ASD 14.0	0.	0.	0.	0.	2.	1.	2.	1.	4.	0.
DUTY 2; ASD 15.0	1.	0.	0.	0.	0.	0.	3.	2.	3.	0.
DUTY 2; ASD 15.0	0.	0.	0.	0.	1.	1.	2.	2.	2.	0.
DUTY 2; ASD 16.0	0.	1.	0.	0.	0.	0.	2.	1.	2.	0.
DUTY 2; ASD 16.0	1.	0.	0.	0.	0.	0.	4.	2.	4.	0.
DUTY 2; ASD 17.0	0.	0.	0.	0.	0.	1.	0.	3.	1.	0.
DUTY 2; ASD 17.0	1.	0.	1.	0.	0.	0.	4.	0.	4.	0.
DUTY 2; ASD 18.0	0.	0.	0.	0.	0.	0.	2.	1.	2.	0.

DUTY 3; ASD 1.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 1.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 2.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 2.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 3.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 3.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 4.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 4.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 5.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 5.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 6.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 6.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 7.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 7.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 8.0	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 8.0	0.	0.	0.	3.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 9.0	0.	0.	0.	4.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 9.0	0.	0.	0.	3.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 10.0	0.	0.	0.	2.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 10.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 11.0	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 11.0	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 12.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 12.0	0.	0.	0.	3.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 13.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 13.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 14.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 14.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 15.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 15.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 16.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 16.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 17.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

DUTY 3; ASD 17.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 3; ASD 18.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 1.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 1.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 2.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 2.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 3.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 3.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 4.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 4.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 5.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 5.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 6.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 6.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 7.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 7.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 8.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 8.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 9.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 9.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 10.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 10.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 11.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 11.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 12.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 12.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 13.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 13.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 14.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 14.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 15.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 15.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 16.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 16.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 17.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 17.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DUTY 4; ASD 18.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROTATIONS THAT HAVE MISSED THEIR GATES

YEAR:	88	89	90	91	92
1ST GATE	0	0	0	0	0
2ND GATE	1	6	26	0	2
3RD GATE	4	9	4	47	31

Sample Output From OUTPUT.DAT

OPTIMAL ASSIGNMENTS FOR FISCAL YEAR 88

ASD YEAR	GATE TIME	FLY	SUP	AFIT	PME	TOTAL ASSIGN
1	1	.00	.00	.00	.00	.00
2	2	.00	.00	.00	.00	.00
3	3	.00	.00	.00	.00	.00
4	4	49.00	.00	.00	.00	49.00
5	5	.00	.00	.00	.00	.00
6	6	.00	1.00	.00	.00	1.00
7	6	.00	6.00	.00	.00	6.00
7	7	.00	25.00	.00	.00	25.00
8	6	.00	.00	.00	.00	.00
8	7	.00	2.00	.00	.00	2.00
8	8	.00	1.00	.00	.00	1.00
9	6	.00	.00	.00	.00	.00
9	7	.00	.00	.00	.00	.00
9	8	.00	.00	.00	.00	.00
9	9	.00	.00	.00	.00	.00
10	6	.00	.00	.00	.00	.00
10	7	.00	.00	.00	.00	.00
10	8	.00	.00	.00	.00	.00
10	9	.00	1.00	.00	.00	1.00
10	10	.00	1.00	.00	.00	1.00
11	6	.00	.00	.00	.00	.00
11	7	.00	.00	.00	.00	.00
11	8	.00	.00	.00	.00	.00
11	9	.00	.00	.00	.00	.00
11	10	.00	.00	.00	.00	.00
11	11	.00	.00	.00	.00	.00
12	6	.00	.00	.00	.00	.00
12	7	.00	.00	.00	.00	.00
12	8	.00	.00	.00	.00	.00
12	9	.00	.00	.00	.00	.00
12	10	.00	.00	.00	.00	.00
12	11	.00	.00	.00	.00	.00
13	6	.00	.00	.00	.00	.00
13	7	.00	.00	.00	.00	.00
13	8	.00	.00	.00	.00	.00
13	9	.00	.00	.00	.00	.00
13	10	.00	.00	.00	.00	.00
13	11	.00	1.00	.00	.00	1.00
14	6	.00	.00	.00	.00	.00
14	7	.00	.00	.00	.00	.00
14	8	.00	.00	.00	.00	.00
14	9	.00	.00	.00	.00	.00
14	10	.00	.00	.00	.00	.00
14	11	.00	.00	.00	.00	.00
15	6	.00	.00	.00	.00	.00
15	7	.00	.00	.00	.00	.00
15	8	.00	.00	.00	.00	.00
15	9	.00	.00	.00	.00	.00
15	10	1.00	.00	.00	.00	1.00

15	11	.00	4.00	.00	.00	4.00
16	6	.00	.00	.00	.00	.00
16	7	.00	.00	.00	.00	.00
16	8	.00	.00	.00	.00	.00
16	9	.00	.00	.00	.00	.00
16	10	.00	.00	.00	.00	.00
16	11	.00	.00	.00	.00	.00
17	6	.00	.00	.00	.00	.00
17	7	.00	.00	.00	.00	.00
17	8	.00	.00	.00	.00	.00
17	9	1.00	.00	.00	.00	1.00
17	10	2.00	.00	.00	.00	2.00
17	11	.00	9.00	.00	.00	9.00
18	6	.00	.00	.00	.00	.00
18	7	.00	.00	.00	.00	.00
18	8	.00	.00	.00	.00	.00
18	9	.00	.00	.00	.00	.00
18	10	1.00	.00	.00	.00	1.00
18	11	6.00	2.00	.00	.00	8.00
19	6	.00	.00	.00	.00	.00
19	7	.00	.00	.00	.00	.00
19	8	.00	.00	.00	.00	.00
19	9	3.00	.00	.00	.00	3.00
19	10	3.00	.00	.00	.00	3.00
19	11	1.00	.00	.00	42.00	43.00
20	6	.00	.00	.00	.00	.00
20	7	1.00	.00	.00	.00	1.00
20	8	.00	.00	.00	.00	.00
20	9	.00	.00	.00	.00	.00
20	10	.00	.00	.00	.00	.00
20	11	.00	.00	.00	4.00	4.00
21	6	.00	.00	.00	.00	.00
21	7	.00	.00	.00	.00	.00
21	8	.00	.00	.00	.00	.00
21	9	.00	.00	.00	.00	.00
21	10	.00	.00	.00	.00	.00
21	11	.00	.00	.00	.00	.00
TOTAL		68.00	53.00	.00	46.00	167.00

DISTRIBUTION OF MISSED FLYING GATES

1ST GAT	.00
2ND GAT	2.00
3RD GAT	41.33

YEAR	DUTY TYPE 1 DESIRABLE 1ST	2ND	ACTUAL 1ST	2ND
88	1710	1710	1028	1143
89	1499	1499	1207	1254
90	1546	1546	1276	1382
91	1588	1588	1381	1380
92	1596	1596	1426	1596
93	1596	1596	1596	1596
94	1596	1596	1598	1597

YEAR	DUTY TYPE 2 DESIRABLE 1ST	2ND	ACTUAL 1ST	2ND
88	1051	1051	121	144
89	1041	1041	147	154
90	1038	1038	141	138
91	930	930	110	116
92	924	924	75	120
93	924	924	128	141
94	924	924	184	235

YEAR	DUTY TYPE 3 DESIRABLE 1ST	2ND	ACTUAL 1ST	2ND
88	33	33	17	18
89	33	33	18	1
90	33	33	8	8
91	29	29	7	7
92	29	29	6	16
93	29	29	29	29
94	29	29	34	34

YEAR	DUTY TYPE 4 DESIRABLE 1ST	2ND	ACTUAL 1ST	2ND
88	34	34	0	0
89	34	34	0	0
90	34	34	28	33
91	30	30	34	25
92	30	30	31	30
93	30	30	30	36
94	30	30	30	30

BOTTLENECK DATA
This data reflects the number of personnel rotating into flying positions in the year specified.

TIME	NUMBER ROTATING
88 1ST HALF	9.0000
88 2ND HALF	1.0000
89 1ST HALF	1.0000
89 2ND HALF	13.0000

APPENDIX D

Plackett-Burman Screen Test																
16-run screen test for 15 main factors																
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Y_1	Y_2
+	+	+	+	-	+	-	+	+	-	-	+	-	-	-	292.04	.8655
-	+	+	+	+	-	+	-	+	+	-	-	+	-	-	36.03	.615
-	-	+	+	+	+	-	+	-	+	+	-	-	+	-	278.74	.8326
-	-	-	+	+	+	+	-	+	-	+	+	-	-	+	207.28	.622
+	-	-	-	+	+	+	+	-	+	-	+	+	-	-	17.00	.613
-	+	-	-	-	+	+	+	+	-	+	-	+	+	-	19.4	.632
-	-	+	-	-	-	+	+	+	+	-	+	-	+	+	17.00	.602
+	-	-	+	-	-	-	+	+	+	+	-	+	-	+	222.50	.742
+	+	-	-	+	-	-	-	+	+	+	+	-	+	-	213.52	.79
-	+	+	-	-	+	-	-	-	+	+	+	+	-	+	256.72	.813
+	-	+	+	-	-	+	-	-	-	+	+	+	+	-	27.4	.669
-	+	-	+	+	-	-	+	-	-	-	+	+	+	+	17.0	.594
+	-	+	-	+	+	-	-	+	-	-	-	+	+	+	236.12	.814
+	+	-	+	-	+	+	-	-	+	-	-	-	+	+	256.72	.847
+	+	+	-	+	-	+	+	-	-	+	-	-	-	+	26.7	.638
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	213.52	.612

Second Screening Design									
2^{8-4} Fractional Factorial									
RET1	RET3	RET4	RET6	OPSDUR	SUPDUR	2GATE	AFIT#	Y_1	Y_2
-	-	-	-	-	-	-	-	218.59	.7964
+	-	-	-	-	+	+	+	262.53	.8876
-	+	-	-	+	-	+	+	90.55	.9589
+	+	-	-	+	+	-	-	97.04	.9629
-	-	+	-	+	+	+	-	100.84	.9386
+	-	+	-	+	-	-	+	109.71	.9614
-	+	+	-	-	+	-	+	233.45	.8571
+	+	+	-	-	-	+	-	221.38	.9164
-	-	-	+	+	+	-	+	97.62	.9617
+	-	-	+	+	-	+	-	88.57	.9766
-	+	-	+	-	+	+	-	327.46	.923
+	+	-	+	-	-	-	+	266.42	.9271
-	-	+	+	-	-	+	+	265.53	.9154
+	-	+	+	-	+	-	-	320.06	.9259
-	+	+	+	+	-	-	-	88.57	.9743
+	+	+	+	+	+	+	+	144.54	.9861

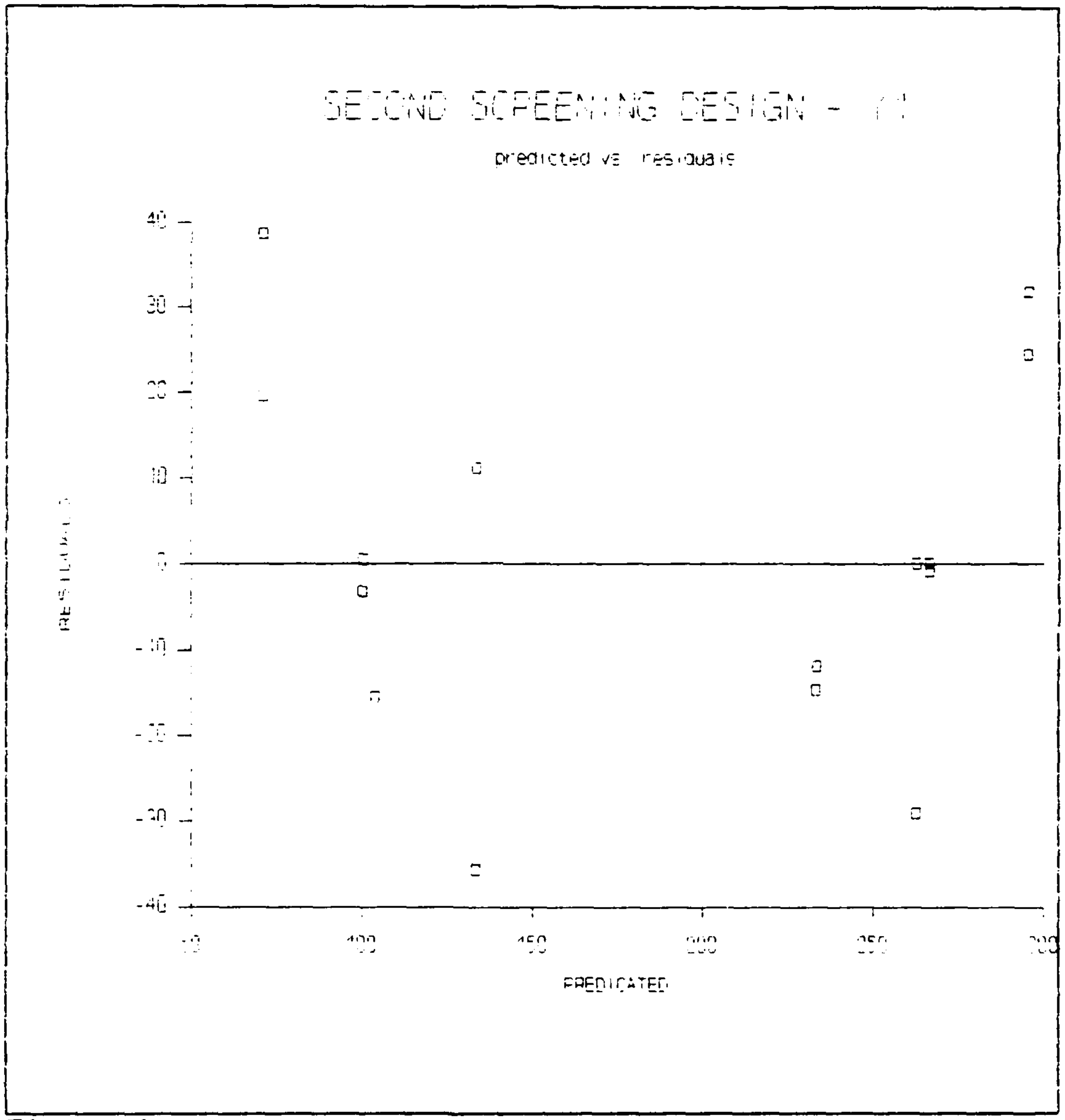
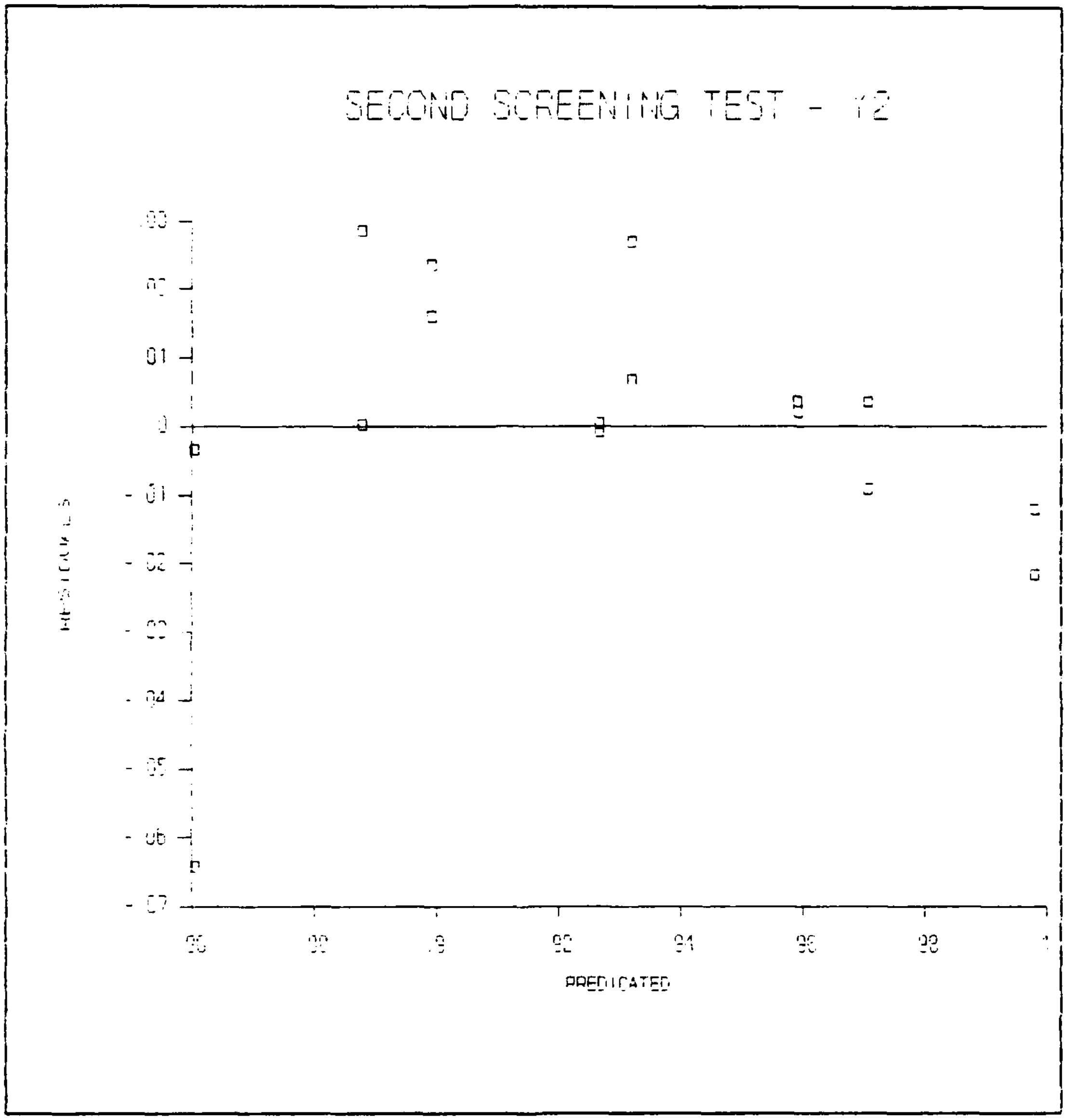

SECOND SCREENING DESIGN -
predicted vs residuals
40
30
20
10
0
-10
-20
-30
-40
400
450
PREDICATED

Figure 1


SECOND SCREENING TEST - Y2
PREDICATED
RESIDUALS

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The purpose of this research was to develop a model which accurately represents the rated officer force and which has the flexibility to represent how different assignment policies affect the system. The managers at the Air Force Military Personnel Center were interested in modeling the rated officer flight gate system. Flight gates are milestones that must be achieved at certain points of a rated officer's career.
This research resulted in selection of a single commodity network flow model with side constraints which also incorporates goal programming techniques. The basic network is designed to represent the rotation of rated officers between flying and nonflying duties. The only flows within the network which have costs associated with them are flows which lead to nonachievement of a flight gate. The objective function is a combination of deviation variables associated with various goals.
Initial results indicate the model offers managers the ability to evaluate conflicting assignment policies. Model shortcomings that need further study include the computer run time and modeling attrition as a dynamic process.